Biology and Management of Diamondback Moth, *Plutella xylostella* (Linn.) on Cabbage

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

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IN

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BY

NAZRUSSALAM

DEPARTMENT OF PLANT PROTECTION
FACULTY OF AGRICULTURAL SCIENCES
ALIGARH MUSLIM UNIVERSITY
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ABSTRACT

Diamondback moth, *Plutella xylostella* (Linn.) (Lepidoptera:Yponomeutidae) is the most devastating insect pest and distributed through out the world. It thrives under extremely varied climatic conditions prevailing in different parts of India. DBM is recorded as a major and oligophagous pest with the larvae feeding specially on the members of the family cruciferae i.e. cabbage, cauliflower, Chinese cabbage, broccoli, knol khol, radish, turnip, and mustard. DBM reproduces year round and completes 13-14 generations in a year.

Population dynamics in relation to abiotic factors prevailing in cropping season is an important component for proper management of the pests. Therefore, seasonal abundance of *P. xylostella* was studied on six varieties of cabbage, *Brassica oleracea* var. *capitata*; Field Man, F1 Deepti, Hybrid-1080, Golden Acre, Cabbage-NS-25 and Diamond Express from October 2007 to April, 2008 and October, 2008 to April, 2009 during Rabi season at 3 locations in the farmer's fields of Aligarh district; Jalali, Mathura Road and G.T. Road which are major cultivating areas of cabbage. Number of larvae and pupae/plant ranged between 0.32 to 4.81 and 1.16 to 6.04 from 40 to 9 std. weeks in Field Man and F1 Deepti, respectively and percent parasitisation ranged between 2.44 to 43.70 and 7.31 to 59.33 from 41 to 9 std. weeks in F1 Deepti and Field Man, respectively in 2007-08 at a temperature fluctuating between 4.79° to 35.07°C with relative humidity of 50.71 to 84.14 percent with scanty rainfall i.e. 0.50mm and 11.60mm at 5 and 6 std. weeks, respectively. While, the density ranged between 0.95 to 5.79 and 0.76 to 5.27 from 40 to 9 std. weeks and percent parasitisation ranged between 2.62 to 57.61 from 40 to 9 std. weeks and 1.57 to 30.18 percent from 42 to 8 std. weeks in the same varieties and place in 2008-09 at 7.36° to 35.86°C and relative humidity of 30.43 to 94.14 percent with scanty rainfall i.e. 6.60mm and 3.20 mm at 47 and 7 std. weeks, respectively.

Number of larvae and pupae/plant ranged between 1.45 to 9.25 and 2.09 to 12.47 and percent parasitisation ranged between 2.99 to 45.45 and 1.18 to 29.0 percent from 47 to 13 std. weeks in Hybrid-1080 and Golden Acre, respectively in 2007-08 at a temperature fluctuating between 4.57° to 34.79°C with relative humidity of 51.0 to 85.0 percent with very scanty rainfall i.e. 0.50mm, 11.60mm, 0.60mm and 0.80mm at 6, 7, 11 and 12 std. weeks, respectively. However, the density increased from 1.28 to 11.66 and 1.08 to 12.56 and percent parasitisation was from 11.33 to 87.96 and 7.26 to 46.34 percent from 45 to 13 std. weeks in the same varieties in 2008-09 at Mathura Road at 7.14° to

32.50°C and relative humidity of 29.43 to 94.29 percent with scanty rainfall i.e. 6.60mm during 47, 3.20mm during 7 and 1.80mm during 13 std. weeks, respectively.

The density ranged between 1.75 to 19.67 and 2.15 to 25.80 larvae and pupae/plant from 50 to 17std. weeks and percent parasitisation ranged between 4.06 to 62.33 and 1.23 to 24.70 percent from 51to 15 and from 1 to 17 std. weeks in cabbage-NS-25 and Diamond Express, respectively in 2007-08 at 5.14° to 38.93°C with relative humidity of 42.29 to 82.57 percent and scanty rainfall i.e. 0.40mm, 11.60mm, 0.50mm, 0.60mm, and 9.60mm at 7, 8, 12, 13 and 15 std. weeks, respectively. Although the intensity of *P. xylostella* was ranging between 2.45 to 24.13 from 49 to 14 std. weeks and 2.55 to 24.50 from 52 to 17 std. weeks in the same varieties and percent parasitisation ranged between 17.81 to 59.52 and 10.35 to 46.63 percent from 52 to 14 and 4 to 17 std. weeks, respectively in 2008-09 at G. T. Road.

Oviposition of *P. xylostella* was studied on *Brassica* hosts in protected field conditions under choice and no-choice tests. Female of *P. xylostella* is significantly preferred to oviposit on cabbage as compared to Indian mustard in both choice and no-choice tests. While, Diamond Express of cabbage was more preferred than that of Hybrid-1080, Golden Acre, F1-Deepti and Field Man in both choice and no-choice tests. Pusa Bold of Indian mustard is more preferred over Varuna and Pusa Bahar in both choice and no-choice tests. Average number of eggs /5females ranged between 14.25 to 16.25 and 109.27 to 138.20 in both choice and no-choice tests, respectively on Indian mustard varieties which were significantly ($P<0.05$) similar during mean of both years, but significantly differed ranged from 25.01 to 73.31 in choice test on cabbage varieties. 204.09 to 623.66 eggs/5 females were ranged on cabbage varieties in no choice test, while F1-Deepti and Field Man were same but rest of the four varieties were significantly differed in no-choice test in mean of both years.

The highest leaf area consumed by the larva of *P. xylostella* was i.e. 15.05, 15.77 cm^2 and 14.97, 15.94 cm^2 and the lowest i.e. 6.21, 7.59 cm^2 and 6.03, 8.83 cm^2 on Diamond Express and Field Man in both choice and no-choice tests during 2007-08 and 2008-09, respectively. Whereas, feeding was statistically similar in Indian mustard varieties in both tests during both years. Hybrid-1080 and Cabbage-NS-25 were found similar, but other four varieties were significantly differed in both tests in 2007-08. F1-Deepti and Field Man were statistically similar, Cabbage-NS-25 and Golden Acre were also recorded similar in no-choice test in 2008-09. Whereas, larva of *P. xylostella* preferred to feed more on Pusa Bold than Varuna and Pusa Bahar of Indian mustard in both tests during both years of study.

Larval survival was studied under protected field condition and at constant temperatures i.e. 10°, 15°, 20°, 25° and 30°C on *Brassica* hosts: 3 cabbage varieties i.e. Field Man, Golden Acre, Diamond Express and 3 Indian mustard; Pusa Bold, Varuna and Pusa Bahar. Larval survival was found to be highest i.e. 80.58 and 82.76 percent on Diamond Express and smallest on Pusa Bahar i.e. 30.84 and 47.76 percent in 2007-08 in both choice and no-choice tests, respectively. Whereas, it was 83.12 and 81.06 percent on Diamond Express and least i.e. 33.39 and 49.26 percent on Pusa Bahar in both tests, respectively in 2008-09. Among cabbage varieties, the lowest survival was on Field Man (40.37 and 50.24 percent) and (39.53 and 54.15 percent) in choice and no-choice tests, respectively during both years of study. Among the Indian mustard, larval survival was highest (35.23, 56.24 percent) and 41.68 and 53.47 percent on Pusa Bold and least on Pusa Bahar, respectively. Larval survival was highest on Diamond Express and the lowest on Field Man on cabbage varieties at all temperatures tested. Among the Indian mustard, survival of larvae was greater on Pusa Bahar at 20°C in comparison to Pusa Bold and Varuna. Larval survival was higher at 20°C on cabbage and Indian mustard varieties as compared to other temperatures.

Life table of *P. xylostella* was studied on *Brassica* hosts: three cabbage varieties; Field Man, Golden Acre, Diamond Express and three Indian mustard; Pusa Bold, Varuna and Pusa Bahar at 22±1°C and 70±5% relative humidity. Survivorship was greater on cabbage varieties than on Indian mustard. Highest number of eggs were hatched on cabbage i.e. Diamond Express followed by Golden Acre and Field Man as compared to Indian mustard. Mortality of egg was highest when *P. xylostella* reared on Pusa Bahar and lowest on Diamond Express. Pre-oviposition period lasted for one day in all the host plants. *P. xylostella* preferred to lay more eggs on cabbage varieties i.e. Diamond Express than other varieties of cabbage and Indian mustard. Total oviposition period was 8-days on Indian mustard while, 9, 10 and 11 days on Field Man, Golden Acre and Diamond Express, respectively. Female birth rate (m_x) was highest when *P. xylostella* fed on Diamond Express while, lowest on Pusa Bahar. Highest potential fecundity (*Pf*) occurred on Diamond Express i.e. 124.05 and lowest on Pusa Bahar i.e. 52.42 females/female/generation followed by on Golden Acre (90.56), Field Man (75.20), Pusa Bold (63.57) and Varuna (55.87).Net reproductive rate (R_0) is significantly ($P<0.05$)

differed on Field Man, Golden Acre, Diamond Express and Pusa Bold and not significantly differed on Varuna and Pusa Bahar. 7.78 females/female/generation were obtained on Varuna and highest i.e. 64.99 on Diamond Express. Highest Intrinsic rate of increase (r_m) occurred on Golden Acre (0.049) and lowest i.e. 0.027 females/female/day on Varuna followed by Diamond Express and Pusa Bold. r_m is significantly ($P<0.05$) reduced when *P. xylostella* reared on Indian Mustard. Lowest finite rate of increase (λ) i.e. 1.027 females/female/day was found on Varuna and highest on Golden Acre i.e. 1.050. Corrected generation time of *P. xylostella* (τ) was 38.01 days on Diamond Express followed by Golden Acre and Field Man. While, almost equal days required to complete one generation on Pusa Bold and Varuna. Population of *P. xylostella* will become double in 6.94 days on Pusa Bold while extended to 10.45 days on Pusa Bahar and 11.15 days on Varuna. *P. xylostella* multiplies fast on cabbage varieties as compared to Indian mustard.

Intercropping of cabbage with non host plants viz., radish, carrot, tomato, garlic, cumin, fennel, coriander, berseem and marigold was studied in two cropping season of 2007-08 and 2008-09 at farmer's field. Population of *P. xylostella* from 10 to 70 DAP then gradually decreases up to harvesting of the crop during both years. Peak population of *P. xylostella* was observed at 70 DAP (days after planting) on cabbage in 2008-09. 15:2 ratio of lines of cabbage+tomato was found to be superior in reducing the incidence of *P. xylostella* on cabbage as compared to 15:1, 25:1 and 25:2 ratio of lines of cabbage+intercrops; radish, carrot, garlic, cumin, fennel, coriander, berseem and marigold. It was followed by garlic, cumin, fennel and coriander. Spacing of cabbage (50x40cm) with intercrops holds more population of DBM larvae and pupae/plant than spacing of 60x45cm. 40-days old seedling of cabbage when planted along with intercrops showed a reduction in larval and pupal population of *P. xylostella* than planting of 30-days old seedling of cabbage in both years of study.

Higher parasitisation was recorded in 30-days old seedling of cabbage than 40-days old seedling and in 60x45 cm spacing than 50x40cm and also in 15:1 ratio than 15:2 during both cropping years. Similarly 25:1 ratio attracted more number of parasites than 25:2 ratios in both the seedling stages and in all the spacing schedules. Significantly highest parasitisation was observed in cabbage + tomato intercrop (23.64 to 60.71 percent) as compared to other cropping system during both years of study. Cabbage + berseem cropping system attracted a considerably lower number of parasites as compared to other intercropping system. Occurrence of parasitoids in cabbage intercropped with garlic, cumin, fennel and coriander was significantly higher as compared to radish, carrot, berseem and marigold cropping system. *Cotesia plutellae* was observed dominant larval parasitoids in the experimental field during both the years.

The highest yield increase was in a range of 47.17 to 61.34 q^{-h} which was produced in cabbage + tomato cropping system and the lowest i.e. 6.30 to 15.00 q^{-h} in cabbage + marigold as compared to cabbage alone. 40-days old seedling of cabbage when planted produced greater yield than 30-days old in all ratios and spacing schedules during both years. Spacing of 60x45 cm with a ratio of 15:2 (cabbage + intercrops) produced higher yield of sole and intercrops than that ratio of 15:1 and also on the same way 25:2 produced maximum yield rather than 25:1. Minimum yield was recorded on cabbage + marigold cropping system in relation to stage of seedling, ratios and spacing. Maximum benefit in terms of rupees was estimated on cabbage + tomato cropping system i.e. Rs. 46440/- in 40-days old seedling of cabbage with 60x45cm spacing and 15:2 ratio during 2008-09. While, it was estimated as Rs. 40870/- in 30-days old seedling of cabbage with the same spacing and ratio in 2007-08 as compared to other cropping system. Cumin, fennel, garlic and coriander intercrops offered greater additional return as compared to radish, carrot, berseem and marigold during both years of study. Comparatively higher yield was recorded in 2007-08 than in 2008-09.

Weather parameters are significantly/non significantly, positively/negatively correlated in both years of study. Maximum and minimum temperature as well as average humidity and rainfall are non significantly (positively/negatively) correlated with ratios and spacing and both seedling stages during both seasons. The minimum temperature was also substantially affected the population of *P. xylostella* and there was negligible rainfall in experimental period of 2007-08. Rainfall substantially affected the population of *P. xylostella* in 2008-09. Maximum and minimum temperature significantly ($P < 0.01$, $P < 0.05$) enhanced the population of *Cotesia* in 30 and 40-days old seedling of cabbage.

Neem azal, neem excel, multineem, neemarin, ultineem, NSKE, cartap hydrochloride and dichlovos were tested against *P. xylostella* on cabbage crop. Neem azal 0.50% EC was significantly ($P<0.05$) the best treatment followed by neem excel 0.15% EC and cartap hydrochloride 50 SP in all the spraying schedules at 30, 50 and 70 days after transplantation (DAT) during both years of 2007-08 and 2008-09. Application of neem azal @ 0.25, 0.50 and 1.00% at 30, 50 and 70 (DAT) was found most effective registering 40.0-63.62%, 60.13-77.02% and 75.24-89.45% reduction in the population of

P. xylostella as compared to control in 2007-08. Whereas 41.79-65.36%, 60.46-76.97% and 75.16-91.86% reduction was obtained in larval population over control in all three round sprays, respectively in 2008-09. Neem azal and neem excel were similar in their efficacy during both years of study. All the treatments produced significantly ($P<0.05$) higher marketable yield of cabbage as compared to control during both years of study. Maximum yield was produced in neem azal i.e. 281.73 and and 275.62 qha^{-1} in 2007-08 and 2008-09, respectively followed by neem excel, cartap hydrochloride and multineem. Lowest yield i.e. 212.43 and 207.60 qha^{-1} of cabbage was recorded in control plot in 2007-08 and 2008-09, respectively. Yield of cabbage in ultineem and NSKE were statistically similar. Yield from neemarin and dichlorvos was also same statistically in both years of study. Neem azal exhibited the highest benefit cost ratio i. e. 13.55:1and 14.02:1 in 2007-08 and 2008-09, respectively. Neemarin showed the lowest benefit cost ratio i.e. 7.81:1and 7.61:1 during both years.

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DEPARTMENT OF PLANT PROTECTION

Dr. M. Shafiq Ansari
Associate Professor

Faculty of Agricultural Sciences,
Aligarh Muslim University
Aligarh- 202 002, India
Phone +91-571-2901524
Mob. No. + 91-9412133609
E-mail : mohdsansari@yahoo.com

CERTIFICATE

This is to certify that the thesis entitled **"Biology and Management of Diamondback Moth, *Plutella xylostella* (Linn.) on Cabbage"** has been completed by **Mr. Nazrussalam** under my supervision. The work is original and has been independently pursued by the candidate.

I permit the candidate to submit for award of the degree of Doctor of Philosophy in Plant Protection (Agriculture) in Entomology of the Aligarh Muslim University, Aligarh.

M. S. Ansari
16-11-2010

M. SHAFIQ ANSARI

DEDICATED TO
MY BELOVED Mother (Ammi)

CONTENTS

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NAZRUSSALAM

INTRODUCTION

Aligarh district is one of the important districts located in the western part of Uttar Pradesh, lies between latitudes (27° 34' N to 28° 11' N) and longitudes (77° 29' E to 78° 38' E) in central part of Ganga-Yamuna doab. The total area of the district has 3, 700 sq.km with a population of 29, 92,286 persons in 2001. The maximum extent of the district from east to west is 116 Km and the maximum extent from north to south is about 62 km. The district has been divided into 5 tehsils namely, Atrauli, Gabhana, Khair, Kole and Iglas. These tehsils are further subdivided into 12 development blocks namely, Atrauli, Gangiri, Bijauli, Jawan, Chandaus, Khair, Tappal, Dhanipur, Lodha, Akrabad, Iglas and Gonda, which include 1180 villages.

Climate of Aligarh district is a typical monsoon type of climate characterized by semi-arid condition. Generally, it is divided into the following four seasons;

(a) Hot weather season (March to mid June)

(b) Season of general rains (mid June to September)

(c) Season of retreating monsoon (October to mid November)

(d) Cold weather season (mid November to February)

Soil of Aligarh district is mostly alluvium. Generally, it is classified in two broad groups' i.e. old and new alluvium. The old alluvial deposits are found above the flood level of the main rivers and their tributaries while the new alluvial deposits are found in the flood affected plains of the rivers and their tributaries. These types of soils are quite productive and useful for the agriculture of the region. Alluvial sandy clay loam soil of Aligarh consists of sand (667 g Kg^{-1}), silt (190 g Kg^{-1}), clay (143 g Kg^{-1}), organic matter (6.2 g Kg^{-1}), nitrogen (N) (0.75g Kg^{-1}), phosphorus (P) (16 mg Kg^{-1}), pH (7.20-8.50) and water holding capacity (0.44 mg g^{-1}).

India is the largest producer of vegetables in the world after China with an annual production of 101.43 million tones from 6.76 million ha of land (Rai and Pandey, 2007). Vegetables play a significant role in nutritionally balanced diet of predominantly vegetarian population of India. Vegetable crops not only provide nutritional security but are also capable of producing more biomass (five times the quantities of food per unit area) as compared to cereal crops. Among Rabi season vegetables, *Brassica*, particularly cabbage and cauliflower, are the most important because of their nutritional and economical values for consumer and producer point of view, and their total share in country's vegetable production is 6.1 and 4.4 percent, respectively (Anonymous, 2005).

India occupies first position in the production of cauliflower and third in cabbage. Major producer of cabbage and cauliflower are Punjab, Haryana, Uttar Pradesh, Bihar, Jharkhand, West Bengal, Assam, Maharashtra, Gujarat and Karnataka. Cabbage (*Brassica oleracea* var. *capitata* Linnaeus) head may be rounded, conical or flat. Round-headed varieties mature earlier followed by conical varieties whereas, flat-headed varieties are usually late. It is a rich source of vitamin A (2000 I.U.), B1 (50 I.U.) and C (124 mg/100g) and also contains various minerals like calcium, phosphorus, potassium, sodium and iron. In Uttar Pradesh, Aligarh district is the major producer of cauliflower and cabbage; the common varieties of cabbage grown by the farmers are Field Man, Prabha, Hybrid-1080, Bronco, F1-Deepti, Golden Acre, Cabbage-NS-25, Diamond Express and Savitri. G.T. road, Mathura road, Panjipur, Jalali, Chhatari and Atrauli are major producing area of cabbage.

Productivity of cabbage and cauliflower in India is much lower attributing to many causes and among them insect pests are the major constraints. The important insect pests associated with cabbage and cauliflower are diamondback moth (DBM), *Plutella xylostella* (Linn.), cabbage butterfly, *Pieris brassicae* (linn.), cabbage borer, *Hellula undalis* (Fab.), leaf-eating caterpillar, *Spilarctia obliqua* (Walker), *Spodoptera littorallis* (Fab.), *S. litura* (Fab.), *S. exigua* (Hubner), leaf-webber, *Crocidolomia binotalis* Zeller, cabbage looper, *Thysanoplusia orichalcea* (Fab.), *Plusia eriosoma* Doubleday, aphids: *Brevicoryne brassicae* (Linn.), *Lipaphis erysimi* (Kalt.), *Aphis gossypii* Glover, *Myzus persicae* (Sulzer), painted bug, *Bagrada cruciferarum* Krikaldy, leaf-eating beetle, *Phyllotreta cruciferae* (Goeze), *P. chotanica* Duviv., *P. birmanica* Harold. These insects are widely distributed in different agro- climatic conditions in India.

Diamondback moth, *Plutella xylostella* (Linn.) (Lepidoptera: Yponomeutidae) has become the most devastating pest throughout the world wherever crucifers are grown (Sarfaraz *et al.*, 2005) and the annual cost of managing this pest is estimated to be US $ one billion (Talekar and Shelton, 1993). DBM thrives under extremely varied climatic conditions prevailing in different parts of India. *P. xylostella* (Linn.) is recorded as a major and oligophagous pest with the larvae feeding specially on the members of the family cruciferae (Thorsteinson, 1953), cabbage, cauliflower, Chinese cabbage, broccoli, knoll khol, radish, turnip, and mustard. In India, it was estimated up to 52 percent loss in marketable cabbage due to diamondback moth (DBM) attack (Krishnakumar *et al.*, 1984) and loss could be more than 80 percent when attack is severe (Chelliah and Srinivasan, 1986). Losses to DBM is estimated to be \$16 million annually in a cultivated area of 0.5 million ha in India (Mohan and Gujar, 2003). A population of 4 or more medium sized DBM larvae (3^{rd} or 4^{th} instar)/plant in a nursery could render seedlings untransplantable and 10 larvae/plant up to one month after planting and 20 larvae/plant 1-2 months after planting caused economic loss and required insecticidal intervention (Jayarathnam, 1977). It has been recorded since 1746 (Harcourt, 1962) and believed to have originated in Mediterranean region (Harcourt, 1954), which is also the place of origin of some of the important crucifer crops (Tsunoda, 1980). It has now been recorded from at least 128 countries or territories of the world and believed to be the most universally distributed of all Lepidoptera (Anonymous, 1968, Talekar and Shelton, 1993. In India, DBM was first recorded on crucifer vegetables in 1914 (Fletcher, 1914) and now it is distributed all over India.

Seasonal incidence of *P. xylostella* has been studied in different agro-climatic conditions of India by several workers (Abraham and Padmanabhan, 1968, Sachan and Srivastava, 1972, Jayarathnam, 1977). High build up larval population has been reported during February and March (late-winter) and April-August (summer and mild rainy season) (Abraham and Padmanabhan, 1968, Sachan and Srivastava, 1972). However, Jayarathnam (1977) and Nagarkatti and Jayanth (1982) found significantly high build up population during rainy season (July-September) as compared to other seasons. DBM can be found on crucifers throughout the year provided that the host crop planted continuously (Lu and Lee, 1984, Talekar and Lee, 1985). Heavy rain is also one of the important factors affecting DBM's abundance (Lu and Lee, 1984, Talekar and Lee, 1985).

Ahmad *et al.* (2009) reported that an outbreak of *P. xylostella* occurred at a greater magnitude in the month of September and October, 2006 on cauliflower at Aligarh district of Uttar Pradesh, India, where the losses were estimated to be 50-100 percent and a number of cauliflower and cabbage fields were completely devastated by DBM and farmers were bound to plough down their fields without any produce even after repeated applications of insecticides. Outbreaks of *P. xylostella* occurred frequently in various parts of the world (Talekar and Shelton, 1993). Besides the quantitative loss the pest also spoil the quality of edible heads and infested crop fetches a very low market price. Control failures with DBM are more common in tropical countries of the world, including India (Saxena *et al.,* 1989, Raju *et al.,* 1994, Ahmad *et al.*, 2009). DBM has the ability to multiply rapidly in the favorable tropical climates due to its high reproductive capacity and wide host range and to develop resistance against an array of insecticides (Talekar *et al.*, 1990). DBM infestations sometimes compel growers to plough down their standing crops in spite of multiple insecticide applications (Abro *et al.*, 1994, Perez *et al.*, 2000). Outbreaks of *P. xylostella* have been reported from Malaysia in 1969 (Wan, 1970), Belarus in 1988, 1991, 1997 and 1998 (Sidlyarevich *et al.*, 2000), Shanghai, China in 1992 and 1994 whereas, losses were estimated to be 99 and 80 percent, respectively (Zhao *et al.*, 1996), Kenya in 1995 (Kibata, 1996), Malaysia in 1997 (Omar and Mamat, 1997), Western Australia in 2001 and New South Wales in 2002 (Endersby *et al.*, 2003), South East Asia in different years and the losses were about 90 percent (Talekar and Shelton, 1993, Verkerk and Wright, 1996), Georgia in USA in 1989 where the loss is estimated as $ 16.4 million (Adams, 1991) and California in 1997 (Shelton *et al.*, 2000). Outbreaks occurred annually throughout the Prairie province of Canada wherever *Brassica* crops are grown (Dosdall *et al.*, 2004). In Alberta and Saskatchewan, Canada where 467,860 ha were treated to control DBM at an estimated cost of CN $ 11.9 million in 1985 (Madder and Stemeroff, 1988), in Canada, 1.25 million ha were treated to control another outbreak at an estimated cost of CN $ 50 million in 1995 (WCCP, 1995), In Western Canada, 1.8 million ha were sprayed with insecticides to control DBM in 2001 (WCCP, 2001). In Texas, USA, losses were $ 40-70 million for cabbage and $ 4, 00,000 for broccoli in 2004 (Shelton, 2004) and in New York $ 80 million for broccoli in 2004 (Shelton, 2004).

Adult moth is small cylindrical, light brownish or grayish in color with wing expanse of 1.4 cm and live for 3-11 days. The male is smaller than female in size. Three pale-whitish triangular patches or wavy markings can be seen on the margins of the fore wings when closed, looks like diamond, this is the reason that common name is diamondback moth (DBM). Life span of male and female is 10 days and 12-18 days, respectively. Adults are inactive during the day, if disturbed during the day, they fly erratically. They were found to be emerging in the evening and rarely in the morning hours. They feed on the flowers of *Brassica* just before dusk. Generally, 13-14 generations are completed per year. Typically minute pale whitish eggs having diameter of 0.5-0.8 mm are laid singly on the lower and upper surface along the mid rib of leaves. A single female lays 50-160 eggs in her life span. The incubation period ranges from 3-7 days and hatching percentage was 80-95 percent depending on the season.

I instars are minute and have a white greenish transluscent body. After hatching, it mines into leaf and remains there for 4-5 days in cold season, 2-3 days in hot and 3-4 days in rainy season. II instar comes out from the mine and looks like whitish-green in color. After coming out from the mines starts feeding on the lower surface of the leaves. It lasts 2-3 days during hot and rainy season and 4-5 days in cold season depending on the varying temperature. III instar is light pale-greenish in color and becomes full grown in 2-3 days in hot and rainy season and 3-5 days in cold season. IV instar is greenish to dark green with creamy brown head and feeds gregariously upon the leaves, which lasts for 2-3 days in hot and rainy seasons and 3-4 days in cold season. Total larval period ranged from 14-21 days (Abraham and Padmanabhan, 1968). The pre-pupal period is estimated to be as one day. Pupation takes place in loose mass of silken cocoon spun by the full grown larva. The pupa is 6 mm long and of light brown in colour (Lingappa *et al.*, 2000) and the period ranges from 7-11 days (Abraham and Padmanabhan, 1968), while 3-7 days with an average of 5 days (Patil and Pokharkar, 1971) and 4 days in hot and rainy seasons, respectively and 4-5 days in cold season (Jayarathnam, 1977). Advance stage larvae bite holes in the leaves. The infestation is more severe during dry season when it causes retardation of growth resulting in undersized cabbage heads. In plains the pest is active during winter while, on the hills attack is more severe during April to August and less during November to March. Life span of male and female is 10 and 12.1 days, respectively (Patil and Pokharkar, 1971). Jayarathnam (1977) reported that the moth survives 3-6 days without food and 11-16 days on food and completes 13 to 14 generations per year. If eggs are laid on the same day of emergence in every generation then there will be about 16 generations per year. Harcourt (1986) reported 4-5 generations per year depending on seasonal temperature, and generation time varies from 18 to 51 days with an average of 25 days in July-August. Devjani and Singh (1999) reported that period of incubation and larval development, duration for the development of pre-pupa, pupa and adult longevity of *P. xylostella* were 2.18, 10.5, 1.6, 6.86 and 16.7 days, respectively. Mean fecundity was 153 eggs per female. However, Sharma *et al.* (1999) found incubation period of eggs of *P. xylostella* was 3-4 days. Larval periods for I, II, III and IV instars were 2-3, 1-1.5, 1-2 and 1.5-2.5 days, respectively. Pupal period ranged from 3-5 days. Longevity of males and females was 6-9 and 14-20 days, respectively. Pre-oviposition, oviposition and post-oviposition periods were 2-4, 6-7 and 5-14 days, respectively. Fecundity varied from 147 to 251 eggs.

Host plants influence the physiology of the insect and thus directly affecting the development leading to shortening or lengthening the duration of different stages. Host plant resistance to oviposition and feeding is an important mechanism by which a plant can limit the amount of damage caused by an insect pest and it is an important component of integrated pest management. Its potential for use against *P. xylostella* on *Brassica* vegetables such as cabbage, cauliflower and broccoli has been studied by several workers. It is widely accepted that larval survival is greatly determined by the oviposition behavior of adult females, as immature stages have limited mobility (Renwick, 1989). Among many herbivore insects, oviposition on newer leaves of a particular host tends to be preferred over oviposition on older leaves (Klemola *et al.*, 2003), which is less suitable for larval development than younger leaves (Raupp *et al.*, 1998, Rodrigues and Pires-Moreira, 1999). Monks and Kelly (2003) investigated the role of learning and host deprivation in host acceptance by adult diamondback moth (*P. xylostella*) in which responsiveness to host is a function of the recent counter rate with host specific stimuli and the oviposition reflex is regulated by non specific causes as eggs load. In *P. xylostella* oogenesis has been shown to increase in the presence of a host plant (cabbage) as compared to non host plant (beans) (Hillyer and Thorsteinsons, 1969) and DBM oviposition was significantly greater on cabbage followed by cauliflower, broccoli and Kohlrabi (Reddy *et al.*, 2004). Contrary to this oogenesis of *P. xylostella* is higher with a non suitable host (*Barbarea vulgaris*) than with the suitable host (cabbage) (Badenes-Perez *et al.*, 2006).Adults of *P. xylostella* are attracted to volatiles emanating from their host plants (Palaniswamy *et al.*, 1986, Pivnick *et al.*, 1990). Three green leaf volatiles have been found in the extract of cabbage and attracted mated females for oviposition (Reddy and Guerrero, 2000). Allyl isothiocynates, the hydrolysis products of mainly aliphatic glucosinolates were found as feeding attractants for DBM and also stimulated enhanced oviposition (Hillyer and Thorsteinson, 1969, Renwick, 2002). While, certain glucosinolates including sinigrin and glucobrassicin and or their metabolites that occur in Brassicaceae were stimulatory to DBM for oviposition (Gupta and Thorsteinson, 1960, Renwick and Radke, 1990). Potent oviposition stimulants for the DBM are extracted from cabbage leaves (Hughes *et al.*, 1997).

Jiang *et al.* (2001) studied the oviposition preference of the DBM, between different *Brassica* vegetable plants and host selection of *Cotesia plutellae* between host larvae on different *Brassica* plant, with the presence of both Chinese cabbage (*B. compestris* subsp. *pekinensis*) and the common cabbage (*B. oleracea* var. *capitata*) and found that DBM moths laid 3 times as many eggs on the former as on the latter plants.

When *C. plutellae* wasps were provided with equal number of larvae of DBM on both plant species in one area, host parasitism rate on Chinese cabbage was almost 5 times more than that on common cabbage.

P. xylostella prefers to oviposit on glossy cabbage because of greener and darker leaves as compared to waxy (normal wax bloom) cultivars (Eigenbrode *et al.*, 1991a, b, Ulmer *et al.*, 2002) but Hamilton *et al.* (2005) found no varietal preference for oviposition by *P. xylostella* for seedling of broccoli or cauliflower while, a highly significant cultivars effect for cabbage in which significantly more eggs were laid on Savoy King than other cultivars. While, significantly more eggs were deposited by female of *P. xylostella* on glossy plants of *B. napus* (Justus *et al.*, 2000) and *B. rapa* (Ulmer *et al.*, 2002) than on their waxy counter parts but females do not discriminate against them as host plants for oviposition (Lin *et al.*, 1984), while larval survival and pupal weight were reduced on such glossy leaved plants (Eigenbrode *et al.*, 1991 a, b, Ulmer *et al.*, 2002, Badenes-Perez *et al.*, 2004).

For pest management program, it is important to develop life tables for pest so that weak links in their life cycle can be properly identified. Life table is a concise summary of certain vital statistics of insect population, which is a useful technique to study in population dynamics and it provides a format for recording and accounting for all population changes in the life of a species in its natural environment (Bilapate *et al.*, 1978). Life table approach was first introduced to insect ecology by Moris and Miller (1954). Later several changes were made in conventional life table to make them useful in economic entomology (Kuno, 1991). Multiple sets of life table data can be analyzed to identify key mortality factors or critical life stages or periods, which can increase understanding of the dynamics of an insect population and at the same time, reveal the most appropriate period for management (Harcourt, 1969, Southwood, 1978). It was extensively studied by Deevy (1947) on natural population of animals. Subsequently, the concept of life table was extended to study the life expectancy of laboratory cultured insects (Birch, 1948, Howe, 1953). Life table has also been used for the study of natural population of insect pests and has been discussed comprehensively by various workers (Morris, 1963, Harcourt, 1969).

Harcourt (1986) compiled 74 life tables of DBM from population and mortality data during 11 year periods and showed that parasites reduced fecundity are the most important factors affecting variation in intra generation survival. Population increases early in the season and is triggered by high female reproductive capacity with maximum number of eggs deposition. Most DBM larvae were killed in immature stages (Harcourt, 1963, 1986, Iga, 1985, Sivapragasam *et al.*, 1988, Wakisaka *et al.*, 1992, keinmeesuke *et al.*, 1992). Seasonal fluctuation and the action of natural enemies (Harcourt, 1963, 1986, Iga, 1985, Wakisaka *et al.*, 1992, keinmeesuke *et al.*, 1992) and precipitation (Harcourt, 1963, Sivapragasam *et al.*, 1988, Talekar and Shelton, 1993) are the major mortality factors. High temperature in hot season and low temperature in cold may affect the survival of immature stages and reduce the adult fecundity (Yamada and Kawasaki, 1983, Keinmeesuke *et al.*, 1992, Wakisaka *et al.*, 1992, Abro *et al.*, 1992, Talekar and Shelton, 1993, Shirai, 2000). While, population dynamics of *P. xylostella* occurred at natural temperature ranging from – 2 to 42°C (Chen, 2002). Net reproductive rate and intrinsic rate of natural increase of a population of *P. xylostella* declined considerably at 33°C (Wakisaka *et al.*, 1992). A higher net reproductive rate can be achieved between 29° and 31°C as larval developmental periods are extremely short at such high temperature (Wakisaka *et al.*, 1992, Shirai, 2000).

In the last 40 years, diamondback moth has become one of the most difficult insect pests in the world to control because of its intrinsic biology and ecology and also its host range. DBM larvae feed on cruciferous vegetables which usually have high cosmetic standards, effective control is necessary and historically the mainstay of control has been the use of synthetic insecticides. The extensive and indiscriminate use of synthetic organic insecticides on cabbage and cauliflower to control the DBM have led to elimination of natural enemies (Ooi and Sudderuddin, 1978, Mani and Krishnamoorthy, 1984, Talekar and Shelton, 1993, Kfir, 2002, Xu *et al.*, 2004) and development of insecticide resistance reported from different states of India (Verma and Sandhu, 1967, Vastrad *et al.*, 2003) .It was the first crop insect reported to have developed resistance to DDT in 1953 in Indonesia (Johnson, 1953). Occurrence of insecticide resistance has also been reported from several countries i.e. South East Asia (Talekar and Shelton, 1993), Japan, (Hama, 1986), USA (Tabashnik *et al.*, 1987), Australia (Altman, 1988), New Zealand (Bell and Fennemore, 1990). *P. xylostella* has developed resistance to as many as 73 insecticides including *B. thuriengiensis* strains and its toxins: http://www.pesticidesresistance. org/DB/ species from more than 50 countries and territories of the world. *P. xylostella* has also been reported with cross resistance and multiple resistant to many insecticides (Shelton *et al.*, 2000, Sayyed *et al.*, 2004, Sarfraz and Keddie, 2005). Development of resistance to most of the insecticides and absence of effective natural enemies, especially parasitoids are believed to be major causes of DBM' key pest status in most parts of the world (Lin *et al.*, 1984).

Therefore, it is clearly needed for an integrated approach instead of sole dependence on chemical pesticides in the management of *P. xylostella*. IPM modules have been developed to manage the pest complex in cabbage and cauliflower (Srinivasan and Krishnamoorthy, 1992, Srinivasan, 1994, Jayaraj *et al.*, 1993, Parmar, 1993, Shukla and Kumar, 2003). Neem based formulations, though initially less effective, their efficacy slowly increased and caused considerable mortality. Earlier study also revealed that neem based formulations causes' low mortality in comparison to insecticides and is mainly known for its antifeedent activity, sterilizing and fitness reducing effects in insect species (Arora and Dhaliwal, 1994). It would be better to alternate the chemical pesticides with effective neem based formulations at proper time in the fields to prevent the chances of developing resistance to pesticides in target insects and undesirable residues in the vegetables.

Neem was described for the first time by Adrien Henri Laurent De Jussieu 1830 as *Azadirachta indica* under family Rutineae (order: Rutales) of dicot plants, although native to India. *A. indica* is found in many parts of Asian, African and American countries where it is known by different local names (Schmutterer, 1995). *A. indica* is widely distributed in India. It is grown in almost all agro-forestry systems and on a variety of sites viz., red meteoritic soil, and poor shallow, strong and sandy soils in arid and semi-arid areas. It can adapt to high temperature of up to 48°C and rainfall between 250 to 1,200 mm. Neem tree has emerged as a single most important source for producing environment friendly organic pesticides besides its high value for its medicinal, fodder, food, oil and timber etc. The species is familiar among local farmers who have developed traditional management technique. Its complex series of bitter constituents are supposed to be actively involved in most of the biological effects on insects. Azadirachtin (Tetranortriterpenoids), a predominant active insecticidal component found in neem seeds and leaves (Butterworth and Morgan, 1968, 1971) and is the best known derivative (Broughton *et al.*, 1986). It is a strong antifeedant and growth disruptor to several insect species and thus a potential candidate for use in plant protection (Ruscoe, 1972, Streets and Schmutterer, 1975, Ladd *et al.*, 1978, Warthen, 1979, Schmutterer and Rembold, 1980) and neem formulations are environmentally safe and low toxic to non target natural enemies (Saxena, 1989). Insect's growth regulations are one of the multiple functions provided by azadirachtin (Rembold *et al.,* 1980). Azadirachtin does not directly kill the pest but alters the life processing behavior in such a manner that the insect can no longer feed, breed or undergo metamorphosis (Elahi, 2008). More specifically, azadirachtin disrupts molting by inhibiting biosynthesis or metabolism of ecdysone (Ware and Whitacre, 2004). Recently, its bio-activity particularly against insect-pests has been investigated in detail (Saxena, 1989, Schmutterer, 1990, Singh, 1993, Martinez and Emden, 1999).

Javaid *et al.* (2000) compared the aqueous neem leaf and seed extracts with parallel dimethoate+cypermethrin against *P. xylostella* on cabbage and reported that all the treatments of neem formulation recorded significantly higher yield of marketable heads of cabbage and also significantly better control of *P. xylostella* than the commonly used mixture of pyrethroids or the untreated control. Lal and Meena (2001) reported that two foliar sprays of cartap hydrochloride (0.05%) at 15 days intervals starting from the appearance of *P. xylostella* on cabbage was recorded the most effective treatment among all the insecticidal applications in both the cropping seasons against *P. xylostella* followed by lambda-cyhalothrin (0.01%), beta-cyfluthrin (0.00125%),, ethofenprox (0.01%), endosulfan (0.07%), and imidacloprid (0.01%). Murthy *et al.* (2006) evaluated 4 commercial neem formulations viz., soluneem, (0.15%), econeem plus (0.30%), vijayneem (0.30%), neemark (0.60%), two plant extracts viz., leaf extracts of *Vitex negundo* and rhizome extracts of *Acrons calamus* (both at 10%), two new insecticide molecules viz., indoxacarb (0.0075%) and fipronil (0.01%) and NSKE (4%) for their efficacy against *P. xylostella* on cabbage and reported that among the treatments, indoxacarb, fipronil and NSKE were found to be effective in reducing the DBM population and recorded significantly higher marketable cabbage heads followed by soluneem, econeem plus, vijayneem and neemark. They also reported that the cost benefit ratio was highest for NSKE (1:9.58) treated plot followed by indoxacarb (1:8.25), fipronil (1:7.66), econeem plus (1:4.99) and vijayneem (1:4.41). Neem formulations are safer to parasites and predators and other non-target organisms than conventional insecticides (Rossner and Zebitz, 1986, Schmutterer and Holst, 1987, Dhaliwal *et al.*, 1997, Pramanic and Chatterjee, 2004, Kumar *et al.*, 2007).

Trap crops, important components of cultural control, are composed of one or more plant species grown to attract a pest species in order to protect a nearby cash crop

(Hokkanen, 1991). Protection may be achieved by preventing the pest from reaching crop, or by concentrating the pest in a portion of field where it can be managed (Shelton and Nault, 2004) and may serve as a resource for natural enemies that can then increase and suppress the pest populations (Zhao *et al.*, 1992). Therefore, this technique has shown some potential to reduce the damage by *P. xylostella* in crucifers. Indian mustard was reported to be a host for *P. xylostella* (Jayarathnam, 1977). Srinivasan and Krishnamoorthy (1992) confirmed the preference for oviposition on Indian mustard by *P. xylostella* as compared to cabbage and larval survival was significantly lower than other plant in laboratory. Charleston and Kfir (2000) observed in laboratory experiments that female DBM prefers to lay more eggs on *B. juncea* than on other *Brassica spp.* which is consistent with previous laboratory and field studies of Andrahennadi and Gillott (1998). Further, Charleston and Kfir (2000) suggested that low larval survival on Indian mustard in the laboratory condition and low infestation in the field, which indicated that the reduced in the wax load of Indian mustard, may play an important role. Asman (2002) used Indian mustard as a trap crop and reported to suppress the damage to cash crop. However, similar approaches have failed in Hawaii (Luther *et al.*, 1996) and Texas (Bender *et al.*, 1999). In a screen-house assessment, adults of *P. xylostella* laid significantly more eggs on *B. vulgaris* than on the cultivated hosts; cabbage, broccoli, and *B. napus* and the larvae do not survive on *B. vulgaris* (Shelton and Nault, 2004). Larval feeding or survival may be reduced in normal bloom varieties through antixenosis and physically or nutritionally based antibiosis (Verkerk and Wright, 1996). If larval period is long then it can afford parasitoids and predators to have more opportunities to attack (Feeny, 1976).

Intercropping is one of the common practices with other crops in many parts of the country and has beneficial effect in reducing the insect pest's damage (Karel *et al.*, 1982). Gautam (1995) also emphasized the need for intercropping in commercial crops to overcome the problem of insect pests and reduction in pesticide use. The role of intercropping is to reduce the incidence of insect pests and enhancing the natural enemy's population in the field. Intercropping/mixed cropping provides an insurance against pests and aberrant weather besides other advantages over sole cropping. Use of intercropping provides an excellent opportunity as an ecological approach in pest management. Intercropping affects the pest by microclimate through changes in crop canopies (Bach and Tabashnik, 1990, and Wu *et al.*, 1999). For some crop insects situation in cropping has reduced pest population because the plants act as a physical barrier to the movement of insect pest. Natural enemies are more abundant and or the chemical or visual communication between insect pests and their host plant is disrupted (Root, 1973, Risch, 1981). Results on DBM and intercropping have been rather variable. It was also found that companion crop may have hidden the host plants significant reduction in eggs and larval densities were found (Theunissen and Schelling,1996, Finch and Kienegger, 1997). The mechanism of visual camouflage, host plants are hidden by taller non-host plants (Finch, 1996), seems to explain the reduction in diamondback moth oviposition.

In addition, crops in intercropping systems may improve soil fertility and the availability of alternative sources of nutrition's products (Risch *et al.*, 1983) as well as reducing the pest attack (Tingey and Lamont, 1988) and lower pest abundance in intercropped or more diverse system to a higher density of predators and parasitoids (Bach, 1980, Khan *et al.*, 1997). The greater density of the natural enemies is caused by an improvement in condition for their survival and reproduction, such as greater temporal and spatial distribution of nectar and pollen sources which can increase parasitoids reproductive potential and abundance of alternative host/prey when the pest species are scarce or at an inappropriate stage (Risch, 1981). It has been observed that cabbage-tomato intercropping lower down the incidence of *P. xylostella* (Buranday and Raros, 1973) and 36 percent reduction in the infestation of *P. xylostella* (Sivapragasam *et al.*, 1982). Intercropping with non-crucifers can also minimize *P. xylostella* infestation (Burandy and Raros, 1975, Talekar *et al.*, 1986, Meena and Lal, 2002, Bukovinszky *et al.*, 2005). Therefore, AVRDC, Taiwan has also suggested that garlic and tomato may be grown as intercrop along with cabbage thereby reducing the infestation of DBM significantly (Anonymous, 1985). While, cabbage intercropped with tomato was proved to be effective in harboring less larvae and pupae of *P. xylostella* (Meena and Lal, 2002).

Favorable climate in winter season for growing of cabbage not only favors the cultivation of cabbage but also creates favorable conditions for infestation and multiplication of DBM on them. Efforts have been made to study the population dynamics of *P. xylostella* on cabbage varieties in relation to its parasites at prevailing conditions of temperature, humidity and rainfall from October, 2007 to March, 2008 and October, 2008 to April, 2009, during Rabi season (winter season) at 3 locations in the farmer's fields of Aligarh district: Jalali, Mathura Road and G.T. Road. Oviposition and feeding behavior as well as larval survival of *P. xylostella* was studied on *Brassica* hosts in field and laboratory conditions under choice and no-choice tests in two cropping seasons of 2007-08 and 2008-09 to determine the most preferred hosts for *P. xylostella*. In these study varieties of cabbage and Indian mustard, *Brassica juncea* were tested because it has previously been shown that *B. juncea* to be a preferred host plant (Srinivasan and Moorthy, 1991). Feeding behavior of *P. xylostella* was also studied on the same *Brassica* hosts under choice and no-choice tests in protected field conditions for the same period. Larval survival was studied on cabbage and Indian mustard varieties under choice and no-choice tests as well as at constant temperatures. The present investigation was undertaken to evaluate preferential response of *P. xylostella* to *Brassica* varieties for oviposition, feeding and larval survival to be cultivated as a trap crop along with cabbage to minimize the load of pesticides and maximize the income of farmers and may also be recommended to farmers to adopt for suitable management of *P. xylostella* on cabbage. Age specific life table of *P. xylostella* was studied on cabbage and Indian mustard varieties to determine the fecundity and life indices to obtain reproduction rate and intrinsic rate of increase so that population trend may be ascertained, required in pest management practices.

During surveys of farmer's fields, it is revealed that generally farmers are using highly toxic chemicals to control the DBM. Excessive and indiscriminate use of pesticides has caused an increasing concern on health hazards, environmental pollution, and residues of insecticides in or on the cabbage consumed as raw and cooked. Therefore, cabbage was intercropped with host/non host plants in relation to transplantation of seedling, ratio of lines of sole and intercrops, spacing of sole crop for two cropping seasons of 2007-08 and 2008-09 to ascertain the most effective intercrop that may be grown in a consistent manner in cabbage fields and it may also be recommended to farmers for sustainable management of *P. xylostella.*

Application of neem based biopesticides against DBM on cabbage at 20 days intervals during the two cropping seasons was also studies for two cropping seasons. In India, Neem based insecticides have been evaluated against 105 species of insect pests (Singh and Kataria, 1991) and they are ecologically safer without adversely affecting the natural enemies.

REVIEW OF LITERATURE

Diamondback moth, *P. xylostella* is distributed in all parts of the world where crucifers are grown (Talekar and Shelton, 1993), and *Brassica* is the most preferred genus (Araiza *et al.*, 1990, Idris and Grafius, 1996). DBM feeds upon all cruciferous plants, cole crops and several greenhouse plants (Reddy *et al.*, 2004) and causing 50-80 % annual loss in marketable yield (Krishnamoorthy, 2002, Devjani and Singh, 1999). In India, estimated loss is about $16 million annually in a cultivated area of 0.5 million ha (Mohan and Gujar, 2003). It thrives under extremely varied agro climatic conditions prevailing in India and it reproduces year round and completes 13-14 generations (Jayarathnam, 1977) and likely does not overwinter (Harcourt, 1960,1986, Butts and McEwen, 1981), although it can develop from 10-35°C (Hardy, 1938). However, Dosdall (1994) reported that populations of DBM could survive at least under mild winter conditions. The DBM has the ability to multiply rapidly in the favorable tropical climates due to its high reproductive capacity and wide host range and to develop resistance against an array of insecticides (Talekar *et al.*, 1990, Shelton *et al.*, 2000, Vastrad *et al.*, 2003, Syyed *et al.*, 2004).

Outbreaks of *P. xylostella* have occurred frequently in various parts of the world (Talekar and Shelton, 1993) that resulted in severe losses (Javier, 1992, Shelton, 2001) and the cost of control is about $ 1 billion (Talekar and Shelton, 1993). In September, 2006 outbreak of DBM has occurred on cauliflower in peri urban area of Aligarh district (U.P.), India (Ahmad *et al.* 2008), where the farmers plough down their field without harvest.

Widespread increased use of insecticides against *P. xylostella* led to elimination of natural enemies (Ooi and Sudderuddin, 1978, Talekar and Shelton, 1993, Xu *et al.*, 2004) and the development of insecticide resistance against a range of insecticides are reported by a number of workers (Verma and Sandhu, 1968, Hama, 1986, Tabashnik *et al.*, 1987, Altman, 1988, Talekar and Shelton, 1993). Resistance to *B. thringiensis* is also known to exist worldwide (Tabashnik *et al.*, 1990, Sayyed *et al.*, 2001).

Garcia (1991) studied the seasonal variation of larvae of *P. xylostella* and of the parasitoid, *Diadegma insulare* in cabbage field in June, with a progressive population decrease to a minimum during November-December. The highest numbers of larvae (14/plant) were recorded at 45 and 60 days after transplanting. Mortality due to Ichneumonid and to diseases varied from 20 to 65% in May and September, respectively and was highest at the end of July and in mid-August (75 and 68%, respectively).

Ichneumonid alone caused an average of 30% mortality, which was highest from the end of July to mid-September. The highest mortality rates due to the parasitoid occurred between the 25 to 35 days and 60 to 70 days after transplanting.

Choi *et al.* (1992) found that the population densities of larvae and pupae of *P. xylostella* were greatest from late June to early July in Chinese cabbage fields. Lengths of the development period from egg to adult were 38.1, 21.7, 16.3 and 12.3 days in females and 38.6, 22.3, 16.5 and 12.5 days in males at 15°, 20°, 25° and 30°C, respectively. The mean threshold temperature of egg-pupa was 8.1°C, and the total effective temperature was calculated as 274 day-°C. *P. xylostella* is, therefore, thought to have 8.4 generations a year. However, Park *et al.* (1993) observed a peak of larval density of *P. xylostella* in mid-October to early November in 1991 and lower in 1992, with 11-12 generations/year (5 in summers, 2-3 in springs and 2 in autumn). Periods required completing a generation were 12-15 days at 26.3°-27.4°C, 16-19 days at 22.5°-23.0°C and 27-33 days at 16.7°-19.7°C. The effective accumulated temperature needed for the entire life cycle was 2 11.4-309.0 day-°C. Eggs required 3.1-4.2 days at 24.9°-27.6°C, 5.1-5.4 days at 21.0°-22.2°C and 7.2-7.8 at 15.2°-19.2°C to hatch. Larval stage was completed in 5.4-6.7 days at 25.4°-28.0°C, 8.2-8.5 days at 22.7°-23.1°C and 10.7-18.3 days at 16.7°-19.5°C. Pupal period was completed in 4.4-6.0 days at 22.0°-28.0°C, 7.2-7.3 days at 20.6°-21.4°C and 8.7-9.2 days at 17.6°-18.6°C. Average adult longevity was 9.5-10.8 days at 25.6°-27.9°C, 12.1-12.6 days at 20.3°-22.8°C and 13.2- 14.2 days at 18.1°-19.9°C. Mean number of eggs laid/female was 118.0-145.2 at 24.4°-28.1°C, 154.6-174.8 at 18.2°-22.1°C and 116.0-144.3 at 14.0°-15.8°C.

The results of Abro *et al.* (1994) indicated that population of *P. xylostella* on the summer cauliflower crop was significantly greater with very wide host ranges than those on the winter crop. The population on cabbage was significantly less than that on cauliflower. Generally, cauliflower and cabbage were the preferred host crops for feeding and population development of *P. xylostella*, followed by radish and turnip. While, Kuwahara *et al.* (1996) used traps baited with a sex pheromone lure and captured a number of *P. xylostella* all year round regardless of different climatic conditions such as dry and rainy seasons. The population density was clearly different between the two fields indicating that the number of emerging insects varied from place to place even in the same season. Population density declined sharply with the harvest of cruciferous vegetables and recovered several weeks after the harvest.

Kandoria *et al.* (1996) reported that larvae of *P. xylostella* were found infesting Brassicaceae host plants throughout the year. A peak was recorded from September to October where the maximum population (35 per plant) was observed during September and the minimum (1.73 per plant) during May. Pupal population was greatest (1.75) in September and lowest (0.01) in July. The maximum number of adults (24.25) was found to be attracted to light traps in October. However, Devjani and Singh (1999) indicated that the maximum abundance of *P. xylostella* was observed during March. Numbers of larvae were correlated with ambient temperature, relative humidity and rainfall. Biology of *P. xylostella* was also studied at 23±1°C and 45±2 percent relative humidity, which revealed that the period of incubation and larval, pre-pupal, pupal and adult longevity were 2.18, 10.5, 1.6, 6.86 and 16.7 days, respectively. Mean fecundity was 153 eggs per female. Saito (1998) surveyed 208 cruciferous crop fields for *P. xylostella* and reported larvae and pupae survived until January or February but no live insects were found in April after each winter season in cabbage fields. Adults were most tolerant to low temperatures and survived for more than two months at 5° and -5°C. Larvae had a relatively low tolerance to low temperatures. Light and pheromone trap catches peaked mostly in summer (July or August), but in some years there was a single peak in May or June. Parasitoids, *C. plutellae, Diadromus subtilicornis* and *Oomyzus sokolowskii* were the most important natural enemies in cabbage fields. The weed, *Radicula sylvestor* acted as a food plant of *P. xylostella* during the spring.

Nathu-Ram *et al.* (2000) studied the varietal resistance of different cabbage varieties/entries against *P. xylostella* under filed conditions during the rabi seasons of 1997-98 and 1998-99. Pride of India and Pusa Drumhead were found highly resistant (means of 0.72 and 0.75, respectively) as per the DBM infestation index. Pusa Synthetic, Golden Acre, Sri Ganesh Gold, Nath 50, Pusa Mukta and BRH-5 recorded moderate resistant; and Quiesto and Copenhagen Market recorded the least resistant. Pride of India and Pusa Drumhead produced the highest mean yields for 2 rabi seasons (290.57 and 295.40 q/ha for Pride of India and 285.40 and 289.75 q/ha for Pusa Drumhead, respectively).

Gonzalez and Macchiavelli (2003) studied the dynamics of *P. xylostella* under intercropping, biological control and *Bt*-based sprays on cabbage (cv. *Izalco)* in a monoculture and in relay-type substitutive dicultures of cabbage/tomato or cabbage/wedelia (*Wedelia trilobata*). Subplots were created by spraying half of the main plots with *Bacillus thuringiensis* (*Bt*) based products. All the treatments, except for the control monoculture, were sprayed with *Bt*-based products in 1999. *C. plutellae*, a larval parasitoid of *P. xylostella* was released argumentatively for biological control. Tomato, as an intercrop, showed a tendency for reducing *P.xylostella* densities in cabbage, reduced the levels of *C. plutellae* parasitism, and competed with cabbage, causing fewer and smaller heads. *C. plutellae* did not regulate *P. xylostella* population, thus, resulting in parasitism levels of 65.3 and 11.6% in the unsprayed monoculture in 1998 and 1999, respectively. The legume *Crotalaria juncea* as a boarder crop did not improve parasitism by *C. plutellae*.

Shukla and Kumar (2003) observed seasonal activity of *C. plutellae* on the larvae of *P. xylostella* infesting cabbage. By monitoring and collecting the samples at weekly intervals starting from the first week of August, it was concluded that *C. plutellae* caused 47.1 and 47.3% parasitization of the pest with peak activity during 11th and 10th standard weeks in both year. Parasitoid activity was positively correlated with pest activity on the cabbage plants.

Khan *et al.* (2004) reported that *P. xylostella* (L.) is the most important insect pest of collard, *B. oleracca* var. *acephala* de condolle. In 1997, the population of diamondback moth larvae generally increased from below the economic threshold level in the early collard crop growth to the above the economic threshold level as crop growth progressed. Host density ranged from 0 to 9.28 larvae and pupae per plant. *Diadegma insulare* was the major parasitoid and parasitism range from 0 to 58.5%. Diamondback moth also parasitized by *O. sokolowskii* kurdjumov (Hymenoptera: Eulophidae). Parasitism by *O. sokolowskii* started later in the season than parasitism by *D. insulare*. Parasitism by *O. sokolowskii* ranged from 0 to 7.3%. Parasitism by *O. sokolowski* and *D. insulare* was inadequate to maintain diamondback moth populations below the economic threshold level in commercial collard fields.

Shukla and Kumar (2004) studied the seasonal incidence of diamondback moth, *P. xylostella* (Linn.) on cabbage at a farmer's field and recorded that *P. xylostella* appeared in the beginning of September and firmly reached to a peak in the last week of November and started declining from the last week of December to the last week of January in 2000-01 and 2001-02, respectively. Again the pest population suddenly increased from February and reached the peak in April. They concluded that temperature is a key abiotic factor in regulating the field population of *P. xylostella*. The hot conditions are congenial environment for multiplication of the pest population in the field while the cold season in November-February limited it. Shukla and Kumar (2004) further studied the seasonal incidence of diamondback moth, *P. xylostella* (Linn.) in relation to abiotic factors in cabbage and reported that *P. xylostella*, started attacking the cabbacge crop initially during the first week of January and the last week of November during 2000-01 and 2001-02, respectively. The population of *P. xylostella* reached to a peak point in 4^{th} standard week of January in both years. The pest population was negatively correlated with mean temperature and mean relative humidity in 2000-01, while a negative correlation with mean temperature and positive correlation with mean relative humidity was recorded in 2001-02.

Nofemela and kfir (2005) studied the role of parasitoids in suppressing *P. xylostella* (L.) (*Lepidoptera: plutellidae*) populations on unsprayed cabbage. Infestations by *P. xylostella* and the incidence of its parasitoids were monitored at weekly intervals and male moths were also monitored at weekly intervals using synthetic sex-pheromone traps. Trap catches indicated that moths were active throughout the year and their flight activity corresponded with larval infestations on the crop. Trap catches and infestation levels were low in summer, autumm and winter (December-August) and high in spring (September-November). Eight indigenous parasitic Hymenoptera were reared from *P. xylostella*: the larval parasitoids, *C. plutellae* (Kurdjumov) (Braconidae) and *Apanteles halfordi* (Ullyett)(Braconidae), larval-pupal parasitoids, *O. sokolowskii* (Kurdjumov) (Eulophidae) and *Diadegma mollipla* Holmgoen (Ichneumonidae), pupal parasitoid, *Diadromus collaris* (Gravenhorst) (Ichneumonidae), and hyperparatoids, *Eurytoma* sp. (Eurytomidae), *Mesochorus sp.*. (Ichneumonidae), and *Pteromalus sp.* (Pteromalidae). Parasitism rates of *P. xylostella* larvae were high reaching 100% on several occasions during late spring, summer and autumn (November-May) each year. Parasitism was lower (<50%) in winter and early spring (June-September). *C. plutellae* was the most abundant parasitoids of *P. xylostella* followed by *O. sokolowskii*. Both parasitoids were active throughout the year. A high rate of parasitism of *P. xylostella* pupae by *D. collaris* was observed only in spring (September-October). Hyperparasitism rates were high in spring and summer (September-Febraury) when upto 35% of collected *P xylopstella* larvae and *C. plutellae* cocoons yielded hyper parasitoids.

Shukla and Kumar (2006) further studied the seasonal activity of pupal parasitoid, *T. sokolowskii* (kurdjumov) [*O. sokolowskii*], on pupae of *P. xylostella* on cabbage. The maximum activity of *T. sokolowskii* recorded during 2nd and 51st standard meteorological weeks in 2000-01 and 2001-02, respectively, with 50% pupal parasitism. *T. sokolowskii* exhibited a positive correlation with the pupal population of *P. xylostella* during both years of experimentation.

Hemchandra and Singh (2007) reported the population dynamics of *P. xylostella* on cabbage agro ecosystem for three cropping seasons (2001-02, 2002-03 and 2003-04). Initially the pest population was very low i.e. 0.01, 0.05 and 0.20 larvae/ plant, during first, second and third years, respectively. Their abundance gradually increased reaching the peak values of 16.15, 28.05 and 20.45 larvae/ plant with the infestation of 90% (2001-02), 70% (2002-03) and 95% (2003-04) during March. During this study, 20 different natural enemies including predators such as 5 birds (*Passerdomesticus indicus, Pycononotuscafer stanferdi, Motacilla alba leucopsis, Streptopelia chinensis suratensis,* and *Zosterops ceylonensis*), 3 syrphids (*Episyrphus balteatus, Ischiodon scutellaris,* and *Sphaerophoria indica*), 3 spiders (*Plexippus paykullii, Oxyopes sp.* and *Plexippus sp.*), 2 ants (*Camponotusbinghami* and *Bothriomyrmex walshi*), 1 dragonfly (*Acisoma panorpoides panorpoides*), 1 *Coccinellid* (*C. septempunctata*) and 5 species of parasitoids (*C. plutellae, D. insulare, D. semiclausum, Brachymeria excarinata, Platylabus sp.*) were observed to be associated with *P. xylostella*. *B. excarinata* and *Platylabus sp.* were observed to be predominant giving higher mortality to DBM as compared to others. The correlation coefficient showed higher temperature, lower relative humidity, lower total rainfall, longer duration of sunshine hours and higher wind speed seemed to be favoured the pest population build up. Further, Hemchandra and Singh (2007) studied *C. plutellae* (Kurdj.), a promising larval parasitoid of *P. xylostella* (Linnaeus) and extent of parasitism of *P. xylostella* larvae by *C. plutellae* ranged from 5.50 to 36.80 percent during 2001 and 10.00 to 36.00 percent during 2002. The parasitoid was active from first week of February to second week of April. Maximum parasitisation of 36.80 percent was on 3rd week of March, 2001 and 36.00 percent on 4th week of March, 2002 synchronized with the maximum incidence of host larvae. Activity of parasitoid was recorded to have a significant positive correlation with incidence of host larval population, temperature and sunshine while negative correlation with relative humidity and total rainfall in both the cropping seasons.

Oviposition of *P. xylostella* is mediated by several sensory modalities including vision, chemoreception and mechanoreception. Consequently, the involvement of glucosinolates in host recognition has been suggested by several studies (Gupta and Thorsteinson, 1960, Reed *et al.*, 1989, Renwick and Radke, 1990). Uematsu and Sakanoshita (1989) suggested that cabbage leaves are basically attractive to ovipositing females of *P. xylostella,* however, the wax bloom on leaves suppresses oviposition and decreases the adhesiveness of eggs. Renwick and Radke (1990) studied oviposition by *P. xylostella* and *P. rapae* on various host plants which showed that despite the similarity in their host ranges, different chemical cues were probably involved in the acceptance or rejection of potential hosts. *P. xylostella* was shown to depend largely on the presence of stimulatory compounds and was not affected by deterrents that caused avoidance of plants in *P. rapae*. It is concluded that a wide range of compounds may be stimulatory to *P. xylostella* whereas *P. rapae* has more specific requirements for acceptance of a plant for oviposition.

Talekar *et al.* (1994) examined the oviposition behavior of *P. xylostella* and observed that females lay eggs mainly on cabbage plant outer leaves. On outer leaves, eggs were laid mainly on the upper leaf surface: on inner leaves they were laid on the lower leaf surface. Egg density decreased from outer to inner leaves. Within a range of 1-11 trichomes/9 mm^2 leaf area, the number of eggs laid on Chinese cabbage leaves increased with trichome density. Most oviposition activity took place within two hours after sunset this period coincides with maximum mating related flying activity. During daylight hours when the plutellid does not normally lay eggs initiation of darkness stimulated oviposition. However, during the night when the pest normally lays eggs artificial light did not reduce oviposition activity.

Idris and Grafius (1996) studied the effects of wild and cultivated *Brassica* on oviposition, egg hatch, larval survival and infestation level of *P. xylostella.* Oviposition by *P. xylostella* was highest on the *Brassica* crops, especially broccoli and lowest on wild *Brassica* especially *Berteroa incana* and *Erysimum cheiranthoides*. Percentage egg hatch was not significantly different among host plants. Larval survival was generally higher on cultivated *Brassica* crops than on wild and there was no survival on *B. vulgaris.* Development time of larvae of *P. xylostella* was generally longer on the wild than on the cultivated *Brassica* crops.

Uematsu and Yoshikawa (2002) revealed that mating of *P. xylostella* primarily began within one or two hours after sunset, although it also occurred during day time in winter. Mating time was longer in cool seasons than in warm seasons. In June to October, oviposition occurred mainly at night with a peak at one or two hours after sunset. In November however, some eggs were laid during day time. Day time oviposition was observed more frequently in colder seasons. It is suggested that a low night temperature suppresses the normal behaviour of the diamondback moth and changes the nocturnal oviposition pattern to a diurnal one. The daily pattern of mating behaviour coincided most closely with that of egg-laying behaviour.

Ulmer *et al.* (2002) indicated that *Brassica* plants expressing the glossy leaves wax characteristics showed some resistance to *P. xylostella*. In oviposition choice test more eggs were laid on 'Glossy' *B. rapa* than on waxy plants though the difference was not significant. Ovipositing females did not discriminate between the 'Glossy' and 'waxy' *B. rapa* lines for oviposition, twice as many I instars were found on 'waxy' *B. rapa* plants than on 'Glossy' plants. In feeding experiment in no choice test, there was no significant difference in the survival of I instar larvae among the four *B. rapa* lines. The lowest survival was on Echo (45%) followed by AcBoreal (47%), waxy (48%) and Glossy (49%). There was no significant difference between larval feeding among four varieties of *B. rapa* and one of *B. napus*. Hamilton *et al.* (2005) studied the effects of cultivar on oviposition preference, larval feeding and development time of diamondback moth, *P. xylostella* (L.) on four cultivars of *B. olaracea* vegetables. They found that there were no differences in the number of eggs laid on the various cultivars of broccoli or cauliflowers. Significantly more eggs were laid on cabbage cultivar Savoy king than any of other cabbage cultivars tested. Larvae developed more rapidly and fed more and for longer on Green Coronet than Savoy king. Musser *et al.* (2005) evaluated glossy leafed collards *B. olaracea* L. var. *acephala* as a potential trap crop for *P. xylostella* because they are attractive to *P. xylostella* adults and are a poor host for *P. xylostella* larvae as compared to cabbage. In 2002, presence of collards within cabbage fields reduced larval density on cabbage. In 2003, trap crop arrangement had no significant impact on larval densities of *P. xylostella*. Egg densities were significantly lower on cabbage than on collards.

Navatha and Murthy (2006) evaluated preference for oviposition and feeding by *P. xylostella* on cabbage, cauliflower, knol khol [kohlrabi] and mustard [Indian mustard] by free-choice, dual-choice and no-choice tests. Under no-choice condition, knol khol (118.0 eggs) followed by cauliflower (74.0 eggs), was more preferred for oviposition, with a mean of 86.5 and 55.0 larvae feeding, respectively. Under dual-choice, mustard combined with cabbage recorded more number of eggs (120.5), while mustard was preferred for larval feeding (82.5 larvae). Combination of mustard with any other host resulted in reduced egg laying on the host in combination. Under free-choice mustard was more preferred for oviposition and feeding. More oviposition and feeding on mustard when grown in combination with other crops indicate its potential as trap crop to curtail the population of *P. xylostella* and reduce insecticidal applications on the main crop.

Badenes-Perez *et al.* (2006) studied the oviposition of diamondback moth in the presence of a highly preferred non-suitable host and found that *P. xylostella* (L.) highly prefers to oviposit on yellow rocket, *B. vulgaris* (R.Br.) (Cruciferae) var. *arcuata*, despite larvae not being able to survive on it, suggesting it may have potential as a trap crop. In a no-choice green house experiment, *P. xylostella* laid 28 percent more eggs on *B. vulgaris* (R. Br.) than on cabbage. Within the *B. vulgaris* plant, *P. xylostella* laid 3.7 times more eggs on younger than older leaves. Furthermore, they demonstrated that in the presence of *B. vulgaris* volatiles, *P. xylostella* laid 2.3 percent more eggs on cabbage plants than in the absence of *B. vulgaris* volatiles. Because increased oogenesis in the presence of *B. vulgaris* could complicate the use of this host as a trap crop for *P. xylostella.* In outdoor screenhouse experiments, *P. xylostella* laid a decreasing percentage of eggs on cabbage as the percentage of *B. vulgaris* increased. In the field, total oviposition in cabbage plots containing *B. vulgaris* was 6.3 times higher than in cabbage plots without *B. vulgaris.* However, in plots with *B. vulgaris*, *P. xylostella* laid 99 percent of the eggs on *B. vulgaris* and oviposition on cabbage plants was 6.2 times lower than in the plots without *B. vulgaris*.

Sarfraz *et al.* (2007) reported that Brassicaceae species and cultivars varied considerably in their susceptibilities as host for *P. xylostella. Sinapis alba* and *B. rapa* plants were highly preferred by ovipositing females. Larval survival was similar on all genotype tested but host plants significantly affected larval and pupal developmental time. Host plants had a significant effect on foliage consumption by individual female and male larvae. Both female and male larvae consumed largest leaf area of *B. rapa*. Whereas, male larvae had least foliage consumption on *B. napus* Liberty. Females and males exhibited a significant difference in life history traits when reared on the same host plant genotypes. Females raised on *B. napus* conquest and *B. juncea* deposited the most total eggs, whereas females from *B. olaracea* laid fewest eggs. Ahmad *et al.* (2008) studied the oviposition of *P. xylostella* on cultivars of *Brassica juncea* (Kranti Pusa Bahar, Pusa Bold, RH-30, Rohni, Vardan and Varuna) and *B. napus* (GSL-1, GSL-2 and Neelam). The result showed that females preferred to lay eggs on *B. napus* as compared to *B. juncea*. The maximum number of eggs was recorded on GSL-2 where the surface of leaf was hairy and glossy and minimum on RH-30.

Saeed *et al.* (2010) obtained a significant difference in the developmental times from egg to pupation of *P. xylostella* on different host plant. The larvae feed on canola (*B. napus*) and mustard (*B. compestris*) developed faster (10.20 and 10.80 days respectively) than other plants but larvae reared on turnip had a longer total development time (13 days). There was no difference in development on cauliflower and cabbage. Survival of *P. xylostella* on cabbage was significantly lower than mustard and lowest on turnip and highest on mustard. Oviposition period was longer (9) on turnip and raddish but 6 days on cabbage. 350 eggs were obtained when larvae reared on canola as compared to other host plants. Fecundity on cabbage and cauliflower was reduced. Egg viability was greater on cauliflower than cabbage, mustard canola and turnip. Net replacement rate was the lowest for population reared on cabbage, which also had the lowest intrinsic rate of population increase as well as reduced mean relative growth rate.

Kandoria *et al.* (1994) studied the biology of *P. xylostella* on cauliflower. The eggs, larval, pre-pupal and pupal periods varied from 1.8 to 5.4, 6.5 to 24.7, 0.7 to 2.4 and 3.3 to 11.4 days, respectively, during different months of year. The corresponding values for their survival were 25-95, 20-80, 50-100 and 50-95 percent, respectively. Pre-copulatory, pre-oviposition and post-oviposition periods were 7.2-63.2h, 0.7-3.5, 2.4-21.4 and 0.5-7.5 days, respectively. Average fecundity was 73.7 eggs during June and 256.4 eggs in December and January. Mean longevity of adult males and females with food was 5.7-32.4 and 4.3-33 days, respectively and without food 1.3-18.2 and 1.2-19.6 days, respectively. In laboratory, the male to female ratio was 1:1.1 and in the field it was 1:1.2. The Yponomeutid had 18 generations per year and the generation period varied from 12 days in June to 44 days during December and January. Devi and Raj (1995) investigated the biology and parasitization of *P. xylostella* infesting cauliflowers. The incubation, larval and pupal periods were 3-4, 5-7, 10-12 days, respectively. Adult longevity was 4-5 days. Total life cycle ranged from 22-28 days during April-May at 28.1°C (mean maximum temperature). Larvae collected from the field were parasitized by *D. fenestrale* and the extent of parasitization varied from 73.33 to 86.67 percent.

Life table approach was first introduced to insect ecology by Moris and Miller (1954). Life table is a concise summary of certain vital statistics of insect population, which is a useful technique to study in population dynamics and it provides a format for recording and accounting for all population changes in the life of a species in its natural environment (Southwood, 1978). Later several changes were made in conventional life table to make them useful in economic entomology (Kuno, 1991).

Wakisaka *et al.* (1991) constructed life tables for *P. xylostella* in a broccoli field in June, September and October 1989. One-third to one-half of individuals disappeared in the early immature stages. Mortality was less in the plots with no rainfall indicating that washing off of eggs and larvae by rain and drowning of young larvae after rain were major mortality factors. The percentage parasitism by the larval parasitoid, *C. plutellae* and the pupal parasitoids, *D. subtilicornis* and *T. sokolowskii* was high in summer. Temperatures higher than 30°C tended to delay development and reduced the survival of immature stages and the fecundity of females. When the moth was fed on the wild cruciferous weed, *C. bursa pastoris*, the reproductive capacity was lowered as compared with that when fed on cultivated crucifers; broccoli, cabbage and Chinese cabbage.

Wang and Chen (1992) studied life tables for *P. xylostella* and found that parasitization of pupae was the most important mortality factor. Natural enemies of *P. xylostella* were adversely affected by cypermethrin and dichlorvos. Biology and survival rate of 2 strains of *P. xylostella* derived from 2 populations collected after rearing in the laboratory for 14 and 15 generations, respectively with chlorfluazuron and without selection was studied by Yamada *et al.* (1993) and suggested that strains which had reacquired high levels of resistance to had a higher intrinsic rate of natural increase than unselected strains, shorter generation times and a higher reproductive rate.

Reddy and Singh (1998) constructed the life table for five generations on cabbage. Parasitism by *C. plutellae* was 13.13, 21.42, 34.17, 29.59 and 36.17 percent during the I, II, III, IV and V generations, respectively in the I larval instar, while during the second larval instar it was 18.33, 21.42, 32.43, 35.84 and 43.33 percent. Generation survival ranged from 0.09 to 0.14. The result showed by Reddy and Singh (1998) that the net reproductive rate representing the total female birth was 3.6078. Population of *P. xylostella* increases, with intrinsic rate of increase of 0.0584 and finite rate of increase (λ) was 1.0602 females per female per day. The mean generation time (T) was 22.05 days and the population on reaching stable age distribution comprised approximately more than 98 percent of immature stages. From the stable age distribution instantaneous birth rate (b) was 0.1639 and death rate of the population was 0.1054.

YuRong *et al.* (2000) collected data by systematic surveys in the field and constructed the natural life tables of two continuous generations of *P. xylostella* L. on flowering Chinese cabbage. Population trend indices of the two generations of DBM were 11.9 and 24.4 in spring and autumn respectively. Parasitoids played an important role in the control of natural populations of DBM. In spring, *O. sokolowskii* (Kurdjumov) for which the exclusive index of population control (EIPC) reached 8.28, while the EIPC of *C. plutellae* (Kurdjumov) was 4.85. In autumn, *C. plutellae* was the second most important factor influencing the natural population of DBM, for which the EIPC was 3.67. The low EIPC (1.2) of *O. sokolowskii* resulted in a high population increase of DBM in autumn. Justin *et al.* (2001) reared freshly hatched larvae or freshly emerged adults of *P. xylostella* on cauliflower, cabbage and Indian mustard to construct the life table. Average duration of immature stages was 21, 22 and 25 days on cauliflower, cabbage and Indian mustard, respectively. Survival from egg to adult emergence was 97.6, 98.4 and 93.6 percent, while maximum longevity of the reproductive female was 16, 16 and 15 days on the aforementioned crops, respectively. Gross reproductive rate of 89.16, 115.40 and 86.78 eggs/female were recorded on cauliflower, cabbage and Indian mustard, respectively. DBM had a capacity for natural increase of 0.16, 0.17 and 0.13 females/female/day on the same crops, respectively. The results also revealed that with a daily finite rate of increase of 1.18, 1.19 and 1.14 females/female/day. DBM population would be multiplied by 3.18, 3.38 and 2.50 times per week, respectively.

Life table of *P. xylostella* was constructed by Syed and Abro (2003) on *Brassica* vegetables; *B. oleracea botrytis, B. oleracea capitata, B. oleracea Italica, B. napus, B. campestris, B. chinensis perkensis* and *R. sativus*. The shortest and longest larval period of 9.45 and 10.95 days were recorded on *B. oleracea* botrytis and *R. sativus*, respectively. Percent larvae pupating did not differ significantly. Lowest and highest percent survival to adult stage was 58.3 and 76.7 percent on *B. napus* and *B. oleracea Italica*. Whereas, shortest and longest pupal period was recorded as 6.48 and 5.84 days on B. napus and *B. oleracea capitata* fed larvae. Highest pupal mass and fecundity was on *B. oleracea* fed larvae as compared to other *Brassica* vegetable crops. Similarly, *P. xylostella* females preferred to lay more eggs on *B. oleracea botrytis* as compared with other hosts. Females preferred to lay eggs on lower side as compared to upper side of the leaves. Net reproductive rate (R_o) was highest when *P. xylostella* fed on *B. oleracea* botrytis, while the lowest of 26.77 on *B. napus*. The intrinsic rate of increase (r_m) and finite rate of increase (λ) were highest and lowest on *B. oleracea botrytis* and *B. campestris*, respectively.

Hemchandra and Singh (2003) studied the life table and age specific table of *P. xylostella* reared on cauliflower under laboratory conditions (22.2±1.0°C and 62.2±3.13 percent relative humidity). Mortality was only 17.3 percent at the egg stage and 60 individuals survived from the egg stage up to adult emergence. The longest duration of the egg, larval and pupal stages were 3, 10 and 5 days, respectively. The female moth lived for 14 days. The female laid eggs from the 21st day of pivotal age until the 34th day. The females contributed the highest number of female progenies (70.013) on the 24th day of pivotal age. The net reproductive rate/generation was 27.19 females/female; with the approximate length of generation time was 26.54 days. Intrinsic rate of increase in population per day was 0.12 female progenies per female whereas; the finite rate of increase per day was 1.13 female progenies per female. The life expectancy of *P. xylostella* declined gradually with age. Again, Hemchandra and Singh (2004) explain the rate of increase and stable age distribution for the *P. xylostella* on knol khol. The net reproductive rate (R_o) was 19.2303 representing total birth with a mean length of generation (T_c) being 32.542 days. The population increase with intrinsic rate of increase (r_m) was 0.0921 and finite rate of increase (λ) was 1.0964 females per female per day. On reaching the stable age distribution the population comprised mainly of immature stages and further life at the time of adult emergence was reduced from 9.51 to 5.27. Life table and female fecundity of *P. xylostella* on *B. juncea* var. rugosa was constructed by Hemchandra and Singh (2005) found that net reproductive rate (R_o) was 24.916, with a mean length of generation (T_c) of 29.428. Intrinsic rate of increase (r_m) was 0.1109 and finite rate of increase of 1. Upon reaching the stable age distribution the population comprised mainly of immature stages and the life duration at the time of adult emergence was reduced from 7.59 to 5.47 days.

Indiscriminate use of insecticides has instigated researchers to look for an alternative such as intercropping, use of resistant host plants, application of biopesticides, and bioagents: predators and parasites.

Intercropping cabbage with other vegetables and herbs are used as a management tool in controlling insect pests of cabbage. Buranday and Raros (1973) studied the effects of cabbage-tomato intercropping on the incidence and oviposition of *P. xylostella*. Significantly higher number of adults and eggs were found in the field containing cabbages only than in the intercropped field, and it is concluded that volatile compounds emitted by the tomato plants repelled adults. Observations on the incidence of adults in intercropped plots in which the number of cabbage rows between 2 tomato rows varied from 1 to 5 indicated that a planting pattern of 2 rows of cabbage between 2 rows of tomato was the most favourable for maintaining the repellent odour and preventing infestation by *P. xylostella* larvae population and damage in collards.

Sivapragasam *et al.* (1982) investigated that tomato contains natural inhibiting chemicals, when intercropped with cabbage reduce infestation of *P. xylostella* by about 36%, but there was no significant reduction in damage. AVRDC, Taiwan recommended that garlic and tomato may be intercropped with cabbage at the same time or 2, 4 weeks earlier, garlic reduced infestation of *P. xylostella* more effectively than tomato in all evaluations (Anonymous, 1985). Chelliah and Srinivasan (1986) reported that intercropping with tomato planted 30 days earlier than cabbage reduced larval damage of *P. xylostella* significantly. However, Talekar *et al.*, (1986) incorporated intercropping in the integrated management of *P. xylostella* with tomato, dill, garlic, safflower, oats and barley and found that these crops reduced the damage by *P. xylostella* to cabbage. They also mentiond that application of tomato leaf extract to cabbage significantly reduced oviposition by *P. xylostella* on treated surfaces. Significant reductions were observed in the larvae of *P. xylostella* and *C. binotalis* when cabbages were planted 30 days after tomatoes and to a lesser extent when they were planted 15 days after the tomatoes in comparison to cabbages alone (Srinivasan and Veeresh, 1986).

Khan *et al.* (1991) grown cabbage intercropped with mustard (*Sinapis alba*)and reported that the number of insecticide applications against diamondback moth (*P. xylostella*) can be reduced from 25 to 8 with a considerable yield increase and costs reduction. Facknath (1997) reported that when cabbage was intercropped with coriander, garlic and tomato plants that caused deleterious effect on *Plutella* populations. However, Asman *et al.* (2001) reported that cabbage intercropped with high red clover, *Trifolium pretense* received fewer eggs of DBM compared with a cabbage monoculture. While, intercropping with low clover did not reduce the amount of egg laid and did not affect the emigration of DBM. . *P. xylostella* can be effectively controlled when cabbage is intercropped with onion, spearmint [*M. spicata*] and tomato after transplanting in the intercropping experiments and both were recommended (Timbilla and Nyako,2001).

Meena and Lal (2002) conducted field experiments during the 1998-99 and 1999-

2000 in rabi seasons to determine the effect of 5 different intercrops on the incidence of *P. xylostella* on cabbage cv. Golden Acre and reported that cabbage intercropped with lucerne recorded the lowest larval population of *P. xylostella* with 9.0 and 8.8 larvae per 10 plants after 12 weeks of transplanting. Cabbage intercropped with garlic recorded 9.3 and 9.6 larvae, while 16.3 and 17.1 in sole crop. Cabbage intercropped with marigold showed a significant difference in the larval population of *P. xylostella* compared to cabbage sole crop in both the years. Cabbage intercropped with tomato harboured 21.5 and 23.3 larvae per ten plants during 1998-99 and 1999-2000, respectively. Cabbage intercropped with Indian mustard did not show any effect on the incidence of *P. xylostella*. Contrary result obtained by Badenes-perez *et al.* (2005a) that intercropping cabbage with tomato or fava beans (*Vicia fava*) did not reduce the number of eggs laid on cabbage. However, Al-Doghairi and Cranshaw (2004) showed that intercropping nectariferous plants with cabbage decrease the population density and increase the parasitism of cabbage pests: *Pieris rapae* (L.), *T. ni* (Hubner), *P. xylostella* (L.) and *B. brassicae* (L.).

Shankar *et al.* (2005) reported that cauliflower intercropped with coriander harboured significantly less DBM larvae as compared to tomato and mustard intercrop treatments. Interaction analysis between inter crops and their cropping pattern clearly showed the significant difference in DBM larval population when cauliflower was intercropped with coriander having cropping pattern of I row of intercrop planted 15 days prior and II row 15 days after the main crop transplantation. However, Uma-Shankar *et al.* (2005) found the impact of intercropping on *P. xylostella* larval population on cauliflower with 2 rows of mustard, tomato and coriander after every 10 rows. While, Asman and Ekbom (2006) did not agree to intercropping as a strategy to reduce oviposition but suggested that the use of trap crop might be a better option because the female will lay her eggs in the trap crop and not get the opportunity to lay them later in life when finally encountering crop plants.

Ali and Bakshi (1994) suggested a 10% visual damage of cabbage plants as a spraying threshold for the management of *P. xylostella*. Shashidhar *et al.* (1994) found the highest percentage leaf damage (98.83) by *P. xylostella* in the cabbage planted in the 1st week of January, followed by that planted in the 1st week of December (48.18). *P. xylostella* also recorded that heads were not marketable in both the cases. They recorded the lowest rate of damage (16.87%) and highest average yield per plot (12.2 kg) in the crop planted in the 1st week of October. Carballo and Hruska (1989) studied the critical period of protection and effect of infestation by *P. xylostella* on the yield of cabbage (CV. Hibrido Izalco). Plots where no insecticide treatment was applied in the first and second stages (pre-formation of heads) produced yields which were not significantly different from those obtained in plots where treatments were applied during the whole cycle. When no protection was applied in the third stage of the crop (formation of heads), 73% yield was reduced. The levels of infestation observed during the first and second stages (0.35 and 7.3 larvae and 5.2 and 49.0 perforations/plant, respectively) did not reduce the yield. The third stage, when levels of infestation were 0.3-5.2 larvae and 6.0-14.2 perforations/plant, was the critical stage, when insecticides should be applied. The economic threshold for the third stage was 0.05-0.4 larvae and 0.2-1.28 perforations/plant, depending on the phenology and the prices of cabbage.

Bio-activity of neem particularly against insect-pests has been investigated in detail (Saxena 1989, Schmutterer, 1990, Singh, 1993, Martinez and Emden, 1999). Its complex series of bitter constituents are supposed to be actively involved in most of the biological effects on insects. The effect of neem on insect parasitoids, predators and other non-target organisms is of particularly interest in integrated pest management and has received much attention from several workers (Joshi *et al.*, 1982, Srivastava and Parmar, 1985, Rossner and Zebitz, 1986, Schmutterer and Holst, 1987) and its use in IPM has been widely recommended (Jayarj *et al.*, 1993, Parmar, 1993).

Patel *et al.* (1996) examined a field experiments with cabbage for the control of *L. erysimi* and *P. xylostella* with 7 insecticides and reported that endosulfan 0.035% (1:37.08), chloropyrifos 0.02% (1:34.08) and neem [*Azadirachta indica*] Seed kernel suspension (NSKS) 3% (1:27.58) the most effective in controlling both pests.

The study conducted by Sannaveerappanavar and Viraktamath (1997) revealed the NSKE at (2.4 percent) caused complete mortality 3rd and 4th instar larvae of *P. xylostella* within in 5-11 days. The majority of 3rd instar died without moulting and all larvae failed to pupate. At lower concentrations of NSKE (0.5 – 1.0 percent), lower mortality was observed, though several surviving larvae either failed to pupate or died in the pupal stage. At all concentrations of NSKE caused a prolongation of the larval period, and death occurred at the time of moulting. It is also recommended that three applications of neem seed Kernel extract were adequate to reduce populations of *P. xylostella* populations of more than 40 per plant to a negligible level.

Moorthy and Kumar (2000) used neem seed kernel extract (4 percent) for managing insecticide resistant diamondback moth. As an alternative to this, neem seed kernel powder extract (NSKP, prepared by dry grinding 4 percent) was found to be effective against *P. xylostella* and *C. binotalis*. Further, the shelf life of NSKP as manifested by its efficiency against the diamondback moth was found to be five months. Reddy and Guerrero (2000) carried out IPM programme on cabbage based on the pheromone trap catch threshold of eight moths per trap per night and also included utilization of the parasitoid, *C. plutellae*. (2, 50,000 adults/ha^{-1}), the predator, *C. carnea* (2,500 eggs ha^{-1}), nimbecidin (625 ml ha^{-1}), *B. thuringiensis* (500 ml ha^{-1}), and phosalone (2.8 L ha^{-1}). IPM Porgramme has induced a reduction of trap catches, egg and larval populations and therefore, a low level of damage to the crop. The economic analysis showed that the cost of the IPM treatments was also considerably lower than that of ordinary insecticide practice (average of \$62 relative to \$123 ha^{-1} respectively). Gross profit was also clearly higher in IPM plots than in farmer's fields, ranging from \$ 777 to \$ 810 ha^{-1} in the IPM plots compared with \$ 456 to \$ 462 ha^{-1} in the insecticide treated fields. As a consequence of lower input costs and higher gross profit, net profit in IPM treatments was even more favourable, and the economic savings associated with the utilization of the IPM programme amounted to \$ 380 ha^{-1} in 1996 and \$ 410 ha^{-1} in 1997.

Lal and Meena (2001) conducted two field trials of insecticides against *P.xylostella* on cabbage during Rabi 1998-99 and 1999-2000. The treatments comprised of beta-cyfluthrin (0.00125%), cartap hydrochloride (cartap) (0.05%), endosulfan (0.07%), imidacloprid (0.01%), ethofenprox (etofenprox) (0.01%), lambda-cyhalothrin (0.01%) and an untreated control. Two foliar sprays of insecticides were applied at 15-day intervals starting from the appearance of insect-pests. Cartap hydrochloride was recorded the most effective treatment among all the insecticidal applications in both the cropping seasons against *P. xylostella* followed by lambda-cyhalothrin, beta-cyfluthrin, ethofenprox, endosulfan and imidacloprid. Ram *et al.* (2001) conducted a field trial from 1997-2000 to evaluate the comparative efficacy of endosulfan (455 g *a.i.*), quinalphos (325 g *a. i.*/ha), fenvalerate (36 g *a.i.*), cypermethrin (65 g *a.i.*), cartap (325 g *a.i.*), two *Btk* formulations (biolep and biobit, both at 750 g *a.i.*), neem oil (*A. indica* oil 1000 g *a.i.*) and NSKE (neem seed kernel extract, 3250 g *a.i.*) against *P. xylostella* on cabbage cv. Copenhagen Market. Quinalphos treatment was highly effective in controlling *P. xylostella* larvae with a maximum yield (200.17 q/ha) and followed by endosulfan, biobit, biolep, cypermethrin and fenvalerate.

Shukla and Kumar (2003) studied the economics of various IPM modules on *P. xylostella* infesting cabbage cv. Golden Acre and reported that the modules consisting of endosulfan (1.25 L/ha)+beta cyfluthrin (7.50 ml/ha)+azadirachtin (2 L/ha) showed a benefit cost (BC) ratio of 9.75:1 and 10.71:1 in two years, respectively, with a pooled mean of 10.25:1. They reported that the maximum BC ratio was recorded in the module consisting of diflubenzuron (200 g/ha)+spinosad (15 g/ha)+azadirachtin (2 L/ha).

Shukla and Kumar (2006) tested the comparative efficacy of various modules against the larvae of *P. xylostella* (Linn.). They found that the application of endosulfian @1.25 lit/hs + beta-cyfluthrin 750 ml/ha + azadirachtin 2.0 lit/ ha proved the best module which reduced larval population and gave the maximum yield followed by *b.t.k.* 1.25kg/ha + diflubenzuron 200g/ha + endosulfan 1.25 lit/ha. Diflubenzuron 200g/ha + spinosad 15 g.a.i/ha + azadirachtin 2.0 lit/ha was proved the least effective with minimum reduction in the larval population. Kumar *et al.* (2007) conducted an experiment during the spring season to evaluate the efficacy of seven insecticides, viz. azadirachtin, *btk*, cartap hydrochloride, spinosad, imidacloprid, beta-cyfluthrin and endosulfan against *P. xylostella* infesting cabbage cv. Golden Acre. All the treatments were recorded significantly superior over the control in reducing the DBM population. Imidacloprid (0.01%) was recorded the most effective by reducing the maximum larval population at each observational interval during first and second spray with the highest marketable yield (228.35 q/ha). Subsequently cartap hydrochloride (0.05%) caused 58.8 to 60.1% reduction in larval population within 14 days of first and second spray. The treatment beta-cyfluthrin (500ml/ha) was recorded effective and economical with a maximum cost benefit ratio of (1:20.02). Satpathy *et al.* (2007) evaluated the bioefficacy of a new molecule, spinosad, alongwith recommended insecticides and *bt* formulation against DBM infesting cabbage.The treatments comprised spinosad (from the soil fungus, *Saccharopolyspora spinosa*), spynosyns A and B (Tracer 2.5 SC), at 15, 17.5 and 20g *a.i.* cypermethrin (Bilcyp 10EC) at 50g *a.i.* quinalphos (Ekalux 25EC) at 250g *a.i.*chlorpyrifos (Dursban 20EC) at 400g *a.i.* *bt* (Biobit 50 WP) at 500g *a.i.* and untreated control. Two sprays of each treatment was applied after attainment of economic threshold level (2-3 DBM larvae per plant). The lowest number of larval population (1.6/plant) was recorded 3 days after the first treatment in spinosad (20g *a.i.*); treated plot being at par with other spinosad and *bt* treatments. Spinosad treatment even at 15g *a.i.* was also recorded superior by the larval population during different pest-treatment periods in controlling DBM larvae. The persistency of this insecticide was found 10 days after treatment on the basis of larval infestation.

MATERIALS AND METHODS

Rearing of DBM:

Larvae and pupae of diamondback moth, *Plutella xylostella* (Linn.) (Lepidoptera: Yponomeutidae) were collected from cabbage and cauliflower cultivated fields of Aligarh district. Collected samples were kept in glass jars (20x10 cm) and provided fresh cabbage leaves and then covered with muslin cloth tightly fixed by rubber band. Jars were maintained at 25±2°C and 70-75 percent relative humidity with 10:14 (L:D). Cabbage was also cultivated at experimental field, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh for fresh supply of food to the mass culture of DBM. Leaves were changed daily in order to maintain hygienic condition. Pupae were sorted out carefully from the jars using a forceps and transferred to another for emergence. Emerged adults were separated and provided 10% honey solution soaked in an absorbent cotton swab for feeding and cabbage leaves for egg laying. Both were changed on every alternate day. Female moth lays creamy-white eggs on both the sides of the leaves. Leaves bearing eggs were removed and kept in another jar for hatching. Eggs were also laid on the walls of jars and were removed by soft camel hair brush and transferred them carefully in Petri plate for hatching. Cabbage leaves were provided to the newly hatched larvae and they mine into leaves. II instars came out from mines and started feeding on leaf surface. II instars changed into III and IV instars and all of them were provided fresh, healthy and tender leaves of cabbage and the process was continued upto the their pupation. Thus, the culture of DBM was multiplied and maintained during the experimental period.

1. Studies on the population dynamics of *P. xylostella* on cabbage:

It was studied on six varieties of cabbage, *B. oleracea.* var. *capitata*; Field Man, F1 Deepti, Hybrid-1080, Golden Acre, Cabbage-NS-25 and Diamond Express from October 2007 to April, 2008 and October, 2008 to April, 2009 during Rabi season at 3 locations in the farmer's fields of Aligarh district; Jalali, Mathura Road and G.T. Road which are major cultivating areas of cabbage. Population of DBM and parasitoids were counted visually from seedlings to harvesting stage. Regular surveys were conducted at weekly interval throughout the cropping season at three locations during both years of study. Collected samples were brought to the laboratory from each variety and with their respective locations. Number of larvae and pupae of *P. xylostella* and cocoons of parasitoids were recorded and kept separately in glass jars and provided fresh leaves of cabbage for pupation. Weak and sluggish larvae were kept for parasitoid emergence. After parasitoid emergence, they were examined and the percentage parasitization was estimated. Finally, the data was analyzed statistically by analysis of variance (ANOVA) to test for both years and variety wise infestation and further subjected to test of significance. Meteorological data for two years was collected from the Meteorological Station, Department of Physics, Aligarh Muslim University, Aligarh.

2. Studies on the oviposition, feeding behaviour and larval survival of *P. xylostella* on *Brassica* hosts:

A. Oviposition behavior of *P. xylostella* on *Brassica* hosts:

Oviposition behaviour of *P. xylostella* was studied under protected field conditions on six varieties of cabbage (*B. oleracea var. capitata*) i.e. Diamond Express, Hybrid-1080, F1 Deepti, Field Man, Golden Acre and Cabbage-NS-25 and three of Indian mustard (*Brassica juncea*) i.e. Pusa Bold, Varuna and Pusa Bahar. Seeds were sown on 15th November of 2007 and 2008 in earthen pots measuring 15 cm in diameter during Rabi season for two consecutive years (2007-08 and 2008-09). The pots were filled up with soil and farm yard manure (FYM) in a ratio of 3:1. Moisture was maintained by light irrigation. Thinning was done at 25 days after sowing (DAS) and only one plant was left in each pot and then (30-days old) plant was exposed for oviposition test.

a. Choice test:

Pots consisting of 30-days old plants of cabbage and Indian mustard varieties were kept altogether in a nylon cage measuring 1x1x1m and five pairs of adults of *P. xylostella* were released inside the cage with 10% honey solution soaked in cotton swab as a food source for adults. The pots were removed after one day of exposure and fresh potted plants of same varieties were kept again for 24-hr. Eggs laid by the female moths were counted on each plant and then calculated the mean number of eggs/5females. The experiment was replicated five times and also the plants bearing the eggs were kept under protected condition for further observations.

b. No-choice test:

Under this procedure, a single potted plant (30-days old) of one variety of cabbage and Indian mustard was kept under a nylon cage measuring 1x1x1 m and then five pair of adults were released into the cage for one day with sugar solution soaked in cotton swab as a food source for adults. Potted plant was removed from the cage and replaced by another one for 24-hr and eggs laid by the female were counted on the plant and kept under protected condition for further observation. Each host plant was replicated ten times.

Thus, two years data were collected and pooled for each variety of *Brassica.* The data were statistically analyzed and least significance difference (LSD) was calculated at 5% significance level.

B. Feeding behavior of *P. xylostella* on *Brassica* hosts:

Standard agronomic practices were carried out for raising the seedling of cabbage and Indian mustard varieties. Before sowing farm yard manure (FYM) was broadcasted and mixed with soil and irrigation was done as required. Seeds of cabbage varieties, Diamond Express, Hybrid-1080, F1-Deepti, Field Man, Golden Acre and Cabbage-NS-25 and Indian mustard varieties, Pusa Bold, Varuna, and Pusa Bahar were sown in micro plots measuring 1x1m on 20th November, 2007 and 2008. Weeding was done 25 days after sowing. Leaves of 30-days old plants of above mentioned varieties were used to study the feeding behavior of larvae of *P. xylostella* under:

a. Bioassay under choice test:

Leaves (30-days old plants) of cabbage and Indian mustard varieties were excised from the plants and kept in bioassay tray measuring 20 cm in diameter. Freshness of leaves maintained by keeping wet cotton on bottom of the bioassay tray and then covered over by muslin cloth. Twenty II instars were obtained from the stock culture and then released in the centre of the bioassay tray. They were allowed to feed up to the pre-pupal stage. Leaves were changed after every 24-hr. A single leaf of each variety was then kept on graph paper and the area consumed by one larva per day was calculated. Each set of experiment was replicated three times and finally the data was subjected to statistical analysis. The same experiment was repeated in next cropping season of 2008-09.

b. Bioassay under no-choice test:

Leaf (30-days old plants) was excised from cabbage and Indian mustard varieties grown in the field. A single leaf was kept in bioassay tray measuring 5 cm in diameter. Five II instars of *P. xylostella* were released in bioassay tray and allowed to feed up to the formation of pre-pupa. Leaf was changed after every 24-hr. Leaf was then kept on graph paper to measure the consumed area by one larva per day. Each set of experiment was replicated five times for each variety of cabbage and Indian mustard. Finally the data was analyzed statistically.

C. Larval survival of *P. xylostella* on *Brassica* hosts:

a. In protected field condition:

Larval survival of *P. xylostella* was studied under protected field condition (choice and no-choice tests) on *Brassica* hosts: three cabbage varieties i.e. Field Man, Golden Acre, Diamond Express and three Indian mustard; Pusa Bold, Varuna and Pusa Bahar for 2007-08 and 2008-09. Potted plants bearing the eggs from choice and no-choice tests were obtained from above mentioned experiments. One hundred eggs were selected. After hatching, observations were made daily on larval survival and mortality of I, II, III, IV instars up to the formation of pre-pupa. Each set of experiment for each variety was replicated three times. Lastly, larval survival was estimated on each host plant separately.

b. At constant temperatures:

Larval survival was studied at constant temperatures i.e. 10°, 15°, 20°, 25° and 30°C on *Brassica* hosts as mentioned in above experiment. At each temperature 10 pairs of adults were sorted out from stock culture. One pair of *P. xylostella* was kept in a glass jar (20X15cm) with cotton swab soaked in 10% honey solution and provided fresh, healthy and tender leaves of each *Brassica* host plant for oviposition. In order to maintain the freshness of leaf, moist soil was wrapped on the petiole of leaf and covered over by polythene and aluminum foil. 2or 3 paper strips were also hanged from the top of jar so as to provide resting sites for adults in each jar. Known number of eggs of the same age were collected to make a batch of 10 eggs and replicated ten times and the experiment was repeated three times. Hatched and unhatched eggs were counted. After hatching, fresh leaf of each host plant was supplied to larvae for feeding in the concerned jar. Survival and mortality was recorded daily on each host plant from the day of hatching to formation of pre-pupa.

3. Studies on the life table of *P. xylostella* on *Brassica* hosts:

Life table of *P. xylostella* was studied at 22±1°C and 70±5% relative humidity on *Brassica* hosts; three cabbage varieties i.e. Field Man, Golden Acre, Diamond Express and three Indian mustard; Pusa Bold, Varuna and Pusa Bahar. Five pairs of adults were kept in a glass jar (20x15 cm) and provided with 10% honey solution soaked in cotton and host leaf for oviposition. In order to maintain freshness of leaf, moist soil was wrapped on the petiole of leaf and then covered over by polythene and aluminum sheet. 2 or 3 paper strips were also hanged from the top of jar so as to provide resting sites for adults. Known number of eggs of the same age were collected to make a batch of 10 eggs and replicated 10 times and the experiment was repeated three times for each host plants. Incubation period was recorded and hatched and unhatched eggs were counted. After hatching fresh host leaf was provided to larvae. Survival and mortality of I, II, III and IV instars were recorded daily. Pre-pupal and pupal periods were determined. Emerged adults were then kept in a jar and pairs were made. One pair of *P. xylostella* was kept in a separate jar and provided 10% honey solution soaked in cotton as a food for adults. Desired host leaf was kept inside the jar for oviposition. In order to maintain the freshness of leaf, moist soil was wrapped on the petiole of leaf and then covered over by polythene and aluminum sheet. Leaf was changed after 24-hr and replaced by a fresh leaf. Eggs were counted daily in order to obtain m_x. This practice was done when the all adults were died. It was replicated ten times. Thus, Age specific, fecundity table and life table indices was constructed by method of Deevey (1947) and Southwood (1978):

x =Age of insect (days)

I_x = Number of surviving at the beginning of age x out of 100

d_x = Number of dying during age intervals x

$100q_x$ = Percentage mortality

e_x = Expectation of life remaining for individuals of age x

$$e_x = \frac{t_x}{I_x.2}$$

Fecundity table is thus constructed with the following assumptions;

(a) Survivorship rates are assumed to be the same for both the sexes, as it is not possible in most of cases to identify the sexes prior to the adult stage.

(b) Sex cannot be identified at egg stage. Therefore, a sex ratio of 1:1 is considered in each batch of eggs.

The table consists of following columns:

x = Pivotal age (days)

I_x = Number of females alive at the beginning of age interval x (x-pivotal age) as a fraction of an initial population of one (Birch, 1948).

m_x = Average number of eggs laid per female in each age interval assuming 50:50 sex ratio and computed as or mean number female offspring produced in a unit time by a female aged (x)

$$m_x = \frac{N_x}{2}$$

Where, N_x = Total natality per female offspring in each age

Besides m_x total number of female offspring in each age interval i.e. female eggs laid in age interval (x)

A number of parameters were also computed from the age specific and fecundity tables, which include:

Potential fecundity (P_f): It expresses the total number of eggs laid by an average female in her life span. It is obtained or calculated by adding up the age specific fecundity (m_x) column and measured in female/female/generation

$$P_f = \Sigma m_x$$

Net reproductive rate (R_0): This is also referred to as the "carrying capacity" of the average insect under defined environmental conditions. The information on the multiplication rate of population in one generation is obtained from it or the number of times a population will multiply per generation. It is denoted as

$$R_0 = \sum I_x . m_x$$

Intrinsic rate of increase (r_m): It is also denoted by r or r_m or r_{max} and called as a biotic potential. It is defined as the instantaneous rate of increase of a population in a unit time under a set of ecological conditions. r_m is calculated by method of Lotka (1925).

$$e^{-rmx} . I_x . m_x = 1$$

Finite rate of increase (λ): Number of times the population will multiply itself per unit time (measured in units of female/females/day) and it is obtained from:

$$(\lambda) = Anti\ log_e\, r_m$$

Mean length of generation (T_c): It is defined as the mean period between the birth of the parent and the birth of offspring. This period is a weighed approximate value or is the mean of period over which progeny are produced and estimated by the formula:

$$T_c = \sum \frac{I_x . m_x . X}{I_x . m_x}$$

Corrected generation time (τ): It is defined as the period from birth of individuals to birth of offspring

$$\tau = log_e\, R_0 / r_m$$

Doubling time (DT): It is defined as the time required for the population to double its number and is calculated as follows:

$$DT = \log_e 2/r_m$$

4. Studies on the management of *P. xylostella* on cabbage:

a. Effect of intercropping on the incidence of *P. xylostella* on cabbage in relation to its parasites:

Field experiments were conducted during two consecutive Rabi seasons of 2007-08 and 2008-09 at Agricultural farm of Faculty of Agricultural Sciences, A.M.U., Aligarh. Nursery of cabbage, *B. oleracea capitata* var. Golden Acre was raised under protected condition in the 2nd week of November during both years at a seed rate of 500gm/ha. Before sowing the seed, nursery bed was irrigated 5 days earlier to maintain the moisture in the soil for proper germination of seed. All recommended agronomic practices were followed for raising the commercial cabbage crop.The intercrops; radish (*Raphanus sativus*), carrot (*Daucus carota L.*), tomato (*Lycopersicom esculentum* Mill), garlic (*Allium sativum*), cumin (*Cuminum cyminum L.*), fennel (*Foeniculum vulgare*), coriander (*Coriandrum sativum* L.), berseem (*Trifolium alexandrinum*) and Marigold (*Tagetes tagetta*) were sown in a random block design in the 2nd week of November during both years. One month after sowing of intercrops, 30 and 40-days old healthy seedlings of cabbage were transplanted in the month of December with spacing of (I) 60x45cm (2) 50x 40cm in a ratio of 15:1(15 lines of cabbage and 1 line of intercrop), 15:2, 25:1 and 25:2 and each treatment was replicated thrice. A parallel control of cabbage (alone) was also runs in each replication. The size of micro plot with 60x45cm spacing was 9.60x2.70m, 10.20x2.70m, 15.60x2.70m and 16.20x2.70m for 15:1, 15:2, 25:1 and 25:2 ratios, respectively and for 50x40cm spacing, 8x2.40m, 8.50x2.40m, 13x2.40m and 13.50x2.40m for 15:1, 15:2, 25:1 and 25:2 ratios, respectively. Each micro plot consists of 6 plants/row with a total of 90 plants and 150 plants with a spacing of 60x45 cm and 50x40 cm in 15:1, 15:2, 25:1 and 25:2 ratios, respectively.

Experiment was conducted under recommended manure and fertilizer doses. FYM @ 250qha^{-1} was mixed in the soil while preparing the field at last ploughing. 150:80:75 Kg NPK ha^{-1} was applied in the form of urea @ 326 Kg, single superphosphate @ 500 Kg and muriate of potash @ 125 Kg ha^{-1}. One third of urea and full quantity of single superphosphate and muriate of potash were applied at the time of transplanting as a basal dressing and the remaining two third quantity of urea was applied in two split doses, one at 30 days after transplanting (DAT) and the other at 50. Light irrigation was given right after transplanting and then irrigation was done at every 10 days interval. Five plants were selected and tagged in each micro plot and natural infestation of *P. xylostella* and its parasites was monitored at 10 days interval after transplanting to the maturity of cabbage. Sick III and IV instars and pupae of *P. xylostella* were brought to laboratory and kept for emergence of adults for proper identification. Data of *P. xylostella* with its parasitoids and total marketable fruit weight of cabbage and yield of concerning intercrops was recorded and analyzed statistically and cost benefit ratio was also worked out. Correlation between weather parameters and average population of *P. xylostella* and its parasitoids was estimated of both years of study.

b. Effect of biopesticides against *P. xylostella* on cabbage:

Field experiments were conducted in Rabi seasons of 2007-08 and 2008-09 in the farmer's field at G.T. Road, Aligarh. The cabbage var. Cabbage-NS-25 was transplanted in the last week of November in the experimental field. The crop was raised with standard agronomic practices. Experiment was laid out in a randomized block design and replicated thrice in a plot size of 6x4 m with 60X50 cm spacing under recommended fertilizer doses 150:80:75 Kg NPK ha^{-1}. All the procedures were followed as mentioned earlier for raising a good commercial crop of cabbage. Observations were made after every 10-day interval on the larval and pupal density on pre-selected and tagged plants of cabbage. Initial infestation occurred at 15 DAT (days after transplantation) and thereafter, density begins to rise and reaching to about 11.72-11.98 and 12.15-12.55 larvae and pupae/plant on cabbage in 2007-08 and 2008-09, respectively at 1˙ day before 30 DAT. This density warrants the application of insecticides to protect the crop. Schedules of commercial neem formulations i.e. neem azal, neem excel, multineem, neemarin, ultineem, (neem based insecticides) and NSKE (indigenously prepared with crude form of neem seeds) and two insecticides, cartap hydrochloride and dichlorvos were used. All neem based insecticides were applied @ 0.25%, 5.0%, and 1.0%, while NSKE (neem seed kernel extract) @ 4.0%, 5.0% and 8.0%, whereas, cartap hydrochloride and dichlorvos were applied @ 0.01%, 0.02% and 0.05% including control plot. Larvae and pupae of DBM were counted on 5 randomly selected plants in each plot at 1 DBS (day before spray).Treatments (I round spray) were applied as a foliar spray with knapsack sprayer. Reduction in density of larvae and pupae/plant was monitored 1, 3, 7 and 10 DAS (days after spray) on cabbage. Percent larval reduction over control was also estimated on these days. 10 days after I round spray, the density tends to increase above economic threshold level, Therefore, II and III round sprays were also carried out at 50 and 70 DAT, respectively. Yield of marketable cabbage heads in Kg per plot was recorded from each plot and converted in quintal per hectare. The data was analyzed statistically and also differences between the treatments were compared using Duncan's multiple range test (DMRT) as well as cost benefit ratio was also worked out.

RESULTS AND DISCUSSION

1. Studies on population dynamics of *P. xylostella* on cabbage:

Population dynamics of *P. xylostella* was studied on six varieties of cabbage *B. oleracea.* var. *capitata*; Field Man, F1 Deepti, Hybrid-1080, Golden Acre, Cabbage-NS-25 and Diamond Express from October 2007 to April, 2008 and October, 2008 to April, 2009 during Rabi season at 3 locations in the farmer's fields of Aligarh district; Jalali, Mathura Road and G.T. Road which are major cultivating areas of cabbage. The infestation of *P. xylostella* was recorded from three locations and varieties mentioned above from the nursery to transplantation of cabbage and to the maturity of crop. The initial infestation of *P. xylostella* was occurred at 40 std. weeks in Field Man and F1 Deepti with an intensity of 0.32 and 1.16 larvae and pupae/plant, respectively in 2007 at Jalali followed by F1 Deepti at an intensity of 0.95 larvae and pupae/plant in 2008 at the same location.

The number of larvae and pupae/plant ranged between 0.32 to 4.81 and 1.16 to 6.04 from 40 to 9 std. weeks in Field Man and F1 Deepti, respectively and percent parasitisation ranged between 2.44 to 43.70 and 7.31 to 59.33 from 41 to 9 std. weeks in F1 Deepti and Field Man, respectively in 2007-08 (Table-1.1). During this period the temperature was fluctuating between 4.79° to 35.07°C with relative humidity of 50.71 to 84.14 percent with scanty rainfall i.e. 0.50mm and 11.60mm at 5 and 6 std. weeks, respectively (Table-1.7). While the density ranged between 0.95 to 5.79 and 0.76 to 5.27 from 40 to 9 std. weeks and percent parasitisation ranged between 2.62 to 57.61 from 40 to 9 std. weeks and 1.57 to 30.18 percent from 42 to 8 std. weeks in F1 Deepti and Field Man, respectively in 2008-09 at Jalali (Table-1.4) at 7.36° to 35.86°C and relative humidity of 30.43 to 94.14 percent with scanty rainfall i.e. 6.60mm and 3.20 mm at 47 and 7 std. weeks, respectively (Table-1.10).

Result (Table-1.2) showed that the number of larvae and pupae/plant ranged between 1.45 to 9.25 and 2.09 to 12.47 and percent parasitisation ranged between 2.99 to 45.45 and 1.18 to 29.0 percent from 47 to 13 std. weeks in Hybrid-1080 and Golden Acre, respectively in 2007-08. During this period the temperature was fluctuating between 4.57° to 34.79°C with relative humidity of 51.0 to 85.0 percent with very scanty rainfall i.e. 0.50mm, 11.60mm, 0.60mm and 0.80mm at 6, 7, 11 and 12 std. weeks, respectively

(Table-1.8). However, the density increased from 1.28 to 11.66 and 1.08 to 12.56 and percent parasitisation was recorded from 11.33 to 87.96 and 7.26 to 46.34 percent from 45 to 13 std. weeks in Hybrid-1080 and Golden Acre, respectively in 2008-09 at Mathura Road (Table-1.5) at 7.14° to 32.50°C and relative humidity of 29.43 to 94.29 percent with scanty rainfall i.e. 6.60mm during 47, 3.20mm during 7 and 1.80mm during 13 std. weeks, respectively (Table-1.11).

The density ranged between 1.75 to 19.67 and 2.15 to 25.80 larvae and pupae/plant from 50 to 17std. weeks and percent parasitisation ranged between 4.06 to 62.33 and 1.23 to 24.70 percent from 51to 15 and from 1 to 17 std. weeks in cabbage-NS-25 and Diamond Express, respectively in 2007-08 (Table-1.3) at 5.14° to 38.93°C with relative humidity of 42.29 to 82.57 percent and scanty rainfall i.e. 0.40mm, 11.60mm, 0.50mm, 0.60mm and 9.60mm at 7, 8, 12, 13 and 15 std. weeks, respectively (Table-1.9). Although the intensity was prevailed between 2.45 to 24.13 from 49 to 14 std. weeks and 2.55 to 24.50 from 52 to 17 std. weeks in Cabbage-NS-25 and Diamond Express, respectively. Percent parasitisation ranged between 17.81 to 59.52 and 10.35 to 46.63 percent from 52 to 14 and 4 to 17 std. weeks in the same varieties, respectively in 2008-09 at G. T. Road (Table-1.6, 1.12).

A significant/ non-significant increase or decrease of *P. xylostella* was recorded from 40 to 17 std. weeks on Field Man, F1 Deepti, Hybrid-1080, Golden Acre, Cabbage-NS-25 and Diamond Express at Jalali, Mathura Road and G.T. Road in 2007-08 and 2008-09, respectively.

Analyzed result showed that the density was significantly/ non-significantly increased from 1st to 9 std. weeks, while it was decreased from 50 to 1st std. weeks at 4.79° to 27.29°C and relative humidity of 53.14 to 80.14 percent with scanty rainfall i.e. 0.5 and 11.60mm during 5 and 6 std. weeks. However, the density of *P. xylostella* was significantly ($P<0.05$)) increased from 40 to 45 std. weeks at 4.79° to 22.93°C with a relative humidity of 52.14 to 82.29 percent and decreased from 45 to 51 std. weeks at 13.21° to 35.07°C with relative humidity of 50.71 to 77.14 percent. The peak population i.e. 4.81 and 6.04 larvae and pupae/plant was recorded at 9 and 45 std. weeks at 10.93° to 27.29°C with relative humidity of 59.29 to 67.29 percent. The maximum parasitisation i.e. 43.70 and 59.33 percent was recorded at 2 and 51 std. weeks at a temperature ranged between 10.36° to 23.29°C with relative humidity of 61.57 to 79.86 percent and at 6.43° to

22.29°C with relative humidity of 53.43 to 80.0 percent in Field Man and F1-Deepti, respectively in 2007-08 at Jalali (Table-1.1, 1.7, Fig. 1.1 A,B).

While, the density was increased significantly ($P<0.05$) from 41 to 44 std. weeks, and decreased from 46 to 51 std. weeks at 17.79° to 35.86°C with relative humidity of 32.43 to 78.57 percent. At 10.86° to 29.86°C with relative humidity of 41.43 to 85.57 percent, it was significantly increased from 40 to 44 std. weeks and decreased from 50 to 1st std. weeks at 17.79° to 35.86°C with relative humidity of 32.43 to 78.57 percent. The peak population i.e. 5.27 and 5.79 larvae and pupae/plant was observed at 46 and 9 std. weeks at 15.0° to 29.86°C with relative humidity of 44.85 to 82.29 percent and 13.43° to 28.57°C with relative humidity of 30.43 to 76.71 percent. The maximum parasitisation i.e. 30.18 and 57.61 percent occurred at 47 and 49 std. weeks at 14.50° to 27.14°C with relative humidity of 44.57 to 84.29 percent with scanty rainfall i.e. 6.60mm during 1 week and 11.29° to 26.14°C with a relative humidity of 43.14 to 84.14 percent in the same varieties, respectively in 2008-09 at the same location (Table-1.4, 1.10, Fig.1.1 C,D).

Density of *P. xylostella* was increasing significantly/non- significantly from 1st to 6 and to 11 std. weeks and non- significantly decreased down from 47 to 49 and again 52 to 1st std. weeks at 4.57° to 22.21°C with relative humidity of 53.29 to 80.29 percent and with scanty rainfall of 0.50mm and 7.0° to 31.50°C with relative humidity of 54.14 to 78.57 percent with 11.60 and 0.60mm rainfall at 7 and 11 std. weeks, respectively and from 11.36° to 28.79°C with relative humidity of 60.0 to 84.86 percent and 6.07° to 22.93°C with relative humidity of 51.0 to 75.86 percent. Whereas, it was significantly/non- significantly increased from 1st to 6 and 7 to 13 std. weeks and at par from 48 to 4 and 5 to 8 std. weeks at a temperature mentioned above and from 7.0° to 34.79°C with relative humidity of 54.14 to 78.57 percent and with scanty rainfall of 11.60mm, 0.60mm and 0.80mm at 7, 11 and 12 std. weeks and from 4.57° to 27.39°C with relative humidity of 51.0 to 85.0 percent. The peak population i.e. 9.25 and 12.47 larvae and pupae/plant was monitored at 11 and 13 std. weeks, respectively at a temperature ranged between 15.64° to 29.79°C with relative humidity of 60.86 to 71.71 percent and with scanty rainfall of 0.60mm during one week. Maximum parasitisation was observed 45.45 and 29.0 percent at 52 and 3rd std. weeks at 8.29° to 22.93°C with relative humidity of 54.29 to 75.86 percent and 8.64° to 20.29°C with relative humidity of 60.0 to 72.43 percent in Hybrid-1080 and Golden Acre, respectively in 2007-08 at Mathura Road (Table-1.2, 1.8, Fig. 1.2 A,B). While, the density was significantly/non- significantly increased from 4 to 10 std. weeks and decreased from 46 to 50 std. weeks at 9.86° to 31.79°C with relative humidity of 29.43 to 88.0 percent and with scanty rainfall of 3.20mm during 1st std. week. The highest population i.e. 11.66 and 12.56 larvae and pupae/plant was monitored at 10 and 13 std. weeks at 15.07° to 31.79°C with relative humidity of 32.71 to 72.0 percent and scanty rainfall of 1.80mm. The highest parasitisation i.e. 87.96 and 46.34 percent was observed at 4 and 51 std. weeks at 10.79° to 23.50°C with relative humidity of 51.43 to 85.71 percent and 12.93° to 23.43°C with relative humidity of 53.86 to 84.29 percent in the same varieties, respectively in 2008-09 at the same place (Table-1.5, 1.11, Fig. 1.2 C,D).

The population of *P. xylostella* was increasing significantly/non- significantly from 8 to 15 std. weeks and at par from 50 to 52 std. weeks at 8.43° to 34.36°C with relative humidity of 55.71 to 77.57 percent with a scanty rainfall of 11.60mm 0.50mm 0.60mm and 9.60mm at 8, 12, 13 and 15 std. weeks and at 7.14° to 23.93°C with relative humidity of 54.29 to 82.57 percent while it was monitored increasing from 5 to 17 std. weeks and it was also recorded at par from 52 to 3 and from 4 to 7 std. weeks at 5.14° to 38.93°C with relative humidity of 42.29 to 78.43 percent with scanty rainfall of 0.40mm, 11.60mm, 0.50mm, 0.60mm and 9.60mm at 7, 8, 12, 13 and 15 std. weeks (Table-1.3, 1.9). The peak population was monitored as 19.67 and 25.80 larvae and pupae/plant at 15 and 17 std. weeks at 17.29° to 30.36°C with relative humidity of 65.29 to 75.57 percent and with scanty rainfall of 9.60mm during that week. The highest parasitism i.e. 62.33 and 24.70 percent was observed at 12 and 7 std. weeks, respectively at a temperature ranged between 16.21° to 32.0°C with relative humidity of 59.14 to 68.43 percent and with scanty rainfall of 0.50mm in a week in Cabbage-NS-25 and Diamond Express, respectively in 2007-08 at G.T. Road (Table-1.3, 1.9, Fig. 1.3 A&B). Whereas the number of larvae and pupae/plant was increasing significantly/non- significantly from 5 to 11std. weeks and was at par from 52 to 4 std. weeks at 9.57° to 32.14°C with relative humidity of 29.43 to 88.0 percent with a scanty rainfall of 3.20mm at 6 std. weeks. While it was significantly ($P<0.05$) increasing from 8 to 12 std. weeks and recorded at par from 52 to 2 std. weeks at 13.07° to 32.64°C with relative humidity of 29.43 to 80.0 percent and with a scanty rainfall of 0.80 mm during that week. The peak population was monitored as 24.13 and 24.50 larvae and pupae/plant at 14 and 17 std. weeks at 19.07° to 35.0°C with relative humidity of 32.0 to 58.43 percent and with 12.0 mm rainfalls during that week. The highest parasitism i.e.

59.52 and 46.63 percent was observed at 8 and 4 std. weeks, respectively in 2008-09 at the same location (Table-1.6, 1.12, Fig. 1.3C&D).

The present investigation revealed that the higher *P. xylostella* population was observed during the month of March and April on Field Man, Hybrid-1080, Golden Acre, Cabbage-NS-25 and Diamond Express during both cropping years, thereafter population abruptly fell down. It was due to the higher temperature which was not congenial to the pest to survive and by then the crop was matured to harvest and there was lack of fresh green leaves for their survival and also prevailing the natural parasitoids and predators. Almost similar duration of incidence was reported by other workers (Gera and Bhatnagar, 1992, Dhaliwal and Goma, 1979, Hemchandra and Singh, 2007) and also variations of peak population of *P. xylostella* in different agro-ecosystem were reported by several workers (Abraham and Padmanabhan, 1968, Yadav *et al.*, 1974; Sachan and Gangwar, 1980, Mulik *et al.*, 2000, Mosiane *et al.*, 2003).

In the present finding, comparatively lower larval and pupal population of DBM were observed in 2007-08 at lower temperature and higher relative humidity than in 2008-09 and scanty rainfall was also favoured the pest population build up during both the years. A number of abiotic and biotic mortality factors interacting together that affect the natural intra generation population dynamics of *P. xylostella* (Harcourt, 1969, Keinmeesuke *et al.*, 1962, Syed and Abro, 2003). Climatic conditions, including higher temperatures and decreased rainfall have been cited as major factors which regulate the population dynamics of *P. xylostella* (Harcourt, 1986), while hot and dry conditions are known to be conducive for *P. xylostella* (Shelton, 2001). Talekar and Shelton (1993) suggested that inversed temperatures can lead to the production of more generation per season. Although, egg production and larval survival of *P. xylostella* are inhibited by temperature above 30°C (Yamada and Kawasaki, 1983). Kuwahara *et al.* (1996) reported that *P. xylostella* maintained consistently high population density through the year even during hottest season of March to May. Compos *et al.* (2006) suggested that seasonal growth in tropical population of *P. xylostella* may be largely dependent on annual pattern of atmospheric circulation. During the present investigation it is also revealed that lower temperature and higher relative humidity adversely affected the population of *P. xylostella.* On the contrary Yamada and Kawasaki (1983) reported that rates of hatching, population and adult emergence were not affected by the levels of humidity. Present finding revealed that scanty rainfall and maximum temperature significantly/non-significantly increased the DBM population and parasitoid activity. Ayalew *et al.* (2006) reported that rainfall and maximum temperature significantly influenced DBM number and parasitoids activity.

Cotesia plutellae (Kurdjumov) was found to be predominant parasite in the study area. Parasitism was reached to 43.70 and 59.33 percent at 2 and 51 std. weeks on Field Man and F1-Deepti, respectively in 2007-08 at Jalali. Parasitism was increased to 87.96 percent at 4 std. weeks of 2009 in Hybrid-1080 at Mathura Road while 62.33 percent at 12 std. weeks of 2008 at a temperature ranged between 16.21° to 32.0°C with relative humidity of 59.14 to 68.43 percent with scanty rainfall of 0.50mm on a week on Cabbage-NS-25 at G.T. Road. It was reported by Mosiane *et al.* (2003) that *C. Plutellae* (Kurdjumov) was most abundant throughout the year and accounted for 55 percent parasitism of *P. xylostella*. *C. plutellae* was also found causing more than 16-70 percent larval parasitism in Gujarat (Yadav *et al.*, 1975) and Bangalore (Jayarathnam,1977, Nagarkatti and Jayanth, 1982) followed by *O.sokolowskii* causing 28-96 percent (Jayarathnam, 1977). However, *C. plutellae* was the dominant larval parasitoid in several parts of India and probably capable of 85.70 percent parasitism (Chandramohan, 1994). Whereas, parasitism of *C. plutellae* was reached to 41.52 percent at a temperature fluctuating between 9.29° to 19.50°C with relative humidity of 67.10 and 73.40 percent while, 46.64 percent parasitism was observed at 5.41° to 20.35°C with relative humidity ranged between 48.10 to 94.0 percent on *P. xylostella* on cauliflower (Ahmad and Ansari, 2010). Chauhan and Sharma (2002) found a total parasitization by all parasitoids varied from 13.4 to 78.3 percent in the period of 1993, 1994 and 1995 and also found that *Diadromus collaris* was the dominant species. Parasitization by *C. plutellae* and *O. sokolowskii* reached to 18-52.50 percent (Alam, 1982, 1991) with an average of 75.0 percent (Alam, 1991).

Population dynamics of *P. xylostella* and its parasites were subjected to Pearson's correlation that showed a positively/negatively significant/non significant correlation under the influence of maximum, minimum and relative humidity during both years of study (Table 1.13 to 1.14). Sujatha *et al.* (1997) reported negative relationship of larval population with temperature and morning relative humidity while it was not significantly positive relationship with evening relative humidity in South India. Whereas, Devjani (1999) reported that among the environmental factors only mean temperature and relative humidity showed significant positive and negative influence, whereas, rainfall showed a weak negative relation with the pest population. Furthermore, Mulik *et al.* (2000) reported that the incidence of DBM population did not show any significant correlation with mean temperature and relative humidity. However, the positive correlation between mean pest population and its associated parasitoids revealed a density dependent relation. Meanwhile, increase in larval and pupal population density and the density of parasitoids also increased in proportionately under field conditions. Rate of parasitization was correlated positively/negatively significant/non-significant to temperature and humidity on *P. xylostella* (Ahmad and Ansari, 2010). Janarti (1982) and Harcourt (1986) also reported similar relationship in cabbage on the similar line. It has been observed in the present study that scanty rainfall during the months of November, February, March and April did not affect the larval population in the field of cabbage varieties and locations. However, contrary result obtained by Ahmad (2008) that larval population of *P. xylostella* decreased down in rainy season and significantly/non-significantly unfavourable for immature stages. However it was also found by Talekar and Shelton (1993) that rain can dislodge the larvae of *P. xylostella* from the plant and can drown the larvae in water and in soil. Sivapragasam *et al.* (1988) reported that rainfall generally wash of 38% of eggs of *P. xylostella* and I instars were found to be susceptible to drowning when they are trapped in water at the leaf axel.

Table-1.1: Population of *P. xylostella* on cabbage at Jalali, Aligarh (October, 2007 to March, 2008)

Months	Std. weeks	Dates (m/d/y)	Var: Field Man				Var: F1-Deepti			
			% plant infested	Larvae and pupae/plant	Larvae and pupae parasitized	% parasitiza-tion	% plant infested	Larvae and pupae/plant	Larvae and pupae parasitized	% parasitiza-tion
October	40	10/6/2007	0.55	0.32a	0.00	0.00	0.00	1.16a	0.00	0.00
	41	10/13/2007	1.65	0.82b	0.02a	2.44	2.44	2.60c	0.19ab	7.31
	42	10/20/2007	2.73	1.05b	0.05a	4.76	4.76	2.95d	0.26bc	8.81
	43	10/27/2007	3.79	1.68c	0.30b	17.86	17.86	3.44e	0.61e	17.73
November	44	11/3/2007	4.17	2.89d	0.45c	15.57	15.57	3.84g	0.73f	19.01
	45	11/10/2007	5.02	3.02e	0.97e	32.12	32.12	6.04k	0.98h	16.23
	46	11/17/2007	5.67	2.97e	0.83d	27.95	27.95	5.85j	1.85k	31.62
	47	11/24/2007	6.11	3.13e	0.91e	29.07	29.07	4.50i	2.07m	46.00
December	48	12/1/2007	6.49	2.76d	0.80d	28.99	28.99	4.15h	1.92kl	46.27
	49	12/8/2007	6.85	2.85d	1.03f	36.14	36.14	3.95g	2.23n	56.46
	50	12/15/2007	7.18	2.98e	0.98e	32.89	32.89	3.50e	1.65j	47.14
	51	12/22/2007	7.33	2.90de	1.09f	37.59	37.59	2.68c	1.59j	59.33
	52	12/29/2007	7.72	2.72d	1.11f	40.81	40.81	3.57e	1.43i	40.06
January	1	1/5/2008	7.89	2.65d	1.07f	40.38	40.38	2.39b	0.95h	39.75
	2	1/12/2008	8.01	2.70d	1.18g	43.70	43.70	3.97g	0.97h	24.43
	3	1/19/2008	8.38	2.95e	1.23g	41.69	41.69	3.66f	0.86g	23.50
	4	1/26/2008	9.14	3.14e	1.34h	42.68	42.68	3.44e	0.72f	20.93
February	5	2/2/2008	9.75	3.46f	1.25g	36.13	36.13	2.48b	0.36d	14.52
	6	2/9/2008	10.44	3.89g	1.31h	33.68	33.68	2.60c	0.19ab	7.31
	7	2/16/2008	10.59	4.01g	1.42i	35.41	35.41	2.55b	0.15a	5.88
	8	2/23/2008	11.67	4.57h	1.55j	33.92	33.92	2.98d	0.12a	4.03
March	9	3/1/2008	12.75	4.81h	1.62j	33.68	33.68			
LSD ($P = 0.05$)				0.25	0.09			0.17	0.07	

Var. = Variety Std. = Standard, m/d/y = Month/day/year Similar alphabets are non significant at 0.05 level by DMRT

Table-1.2: Population of *P. xylostella* on cabbage at Mathura Road, Aligarh (November, 2007 to March, 2008)

Months	Std. weeks	Dates (m/d/y)	Var: Hybrid-1080				Var: Golden Acre			
			% plant infested	Larvae and pupae/plant	Larvae and pupae parasitized	% parasitiza-tion	% plant infested	Larvae and pupae/plant	Larvae and pupae parasitized	% parasitiza-tion
November	45	11/5/2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	46	11/12/2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	47	11/19/2007	2.45	1.67b	0.05a	2.99	3.47	2.55b	0.03a	1.18
	48	11/26/2007	3.79	1.58a	0.13b	8.23	3.50	2.28a	0.11b	4.82
December	49	12/3/2007	4.50	1.55a	0.35f	22.58	3.65	2.23a	0.28c	12.56
	50	12/10/2007	5.63	1.70b	0.57k	33.53	3.89	2.33a	0.49f	21.03
	51	12/17/2007	5.95	1.61a	0.53ij	32.92	4.03	2.35a	0.56gh	23.83
	52	12/24/2007	6.05	1.65b	0.75mn	45.45	4.09	2.48a	0.69j	27.82
	53	12/31/2007	6.19	1.48a	0.50i	33.78	4.15	2.18a	0.53g	24.31
January	1	1/7/2008	6.34	1.45a	0.45h	31.03	4.21	2.09a	0.44e	21.05
	2	1/14/2008	7.60	1.52a	0.39g	25.66	4.57	2.10a	0.39d	18.57
	3	1/21/2008	8.15	1.75b	0.69l	39.43	5.02	2.31a	0.67ij	29.00
	4	1/28/2008	18.56	1.84c	0.33e	17.93	5.33	2.45a	0.65i	26.53
February	5	2/4/2008	18.71	1.95c	0.28cd	14.36	5.45	2.56b	0.66i	25.78
	6	2/11/2008	20.30	2.59d	0.25c	9.65	5.89	2.63b	0.58h	22.05
	7	2/18/2008	20.39	2.53d	0.28cd	11.07	6.05	2.59b	0.64i	24.71
	8	2/25/2008	20.41	3.05e	0.31de	10.16	8.97	2.78b	0.45e	16.19
March	9	3/3/2008	20.65	7.83f	0.43h	5.49	11.35	5.11c	0.71k	13.89
	10	3/10/2008	21.71	9.13g	0.72lm	7.89	15.37	6.29d	0.70jk	11.13
	11	3/17/2008	22.03	9.25g	0.77n	8.32	16.55	8.81e	0.73kl	8.29
	12	3/24/2008					20.49	12.05f	0.75l	6.22
	13	3/31/2008					22.57	12.47f	0.81m	6.50
LSD ($P = 0.05$)				0.17	0.03			0.42	0.03	

Table-1.3: Population of *P. xylostella* on cabbage at G. T. Road, Aligarh (December, 2007 to April, 2008)

Months	Std. weeks	Dates (m/d/y)	Var: Cabbage-NS-25				Var: Diamond Express			
			% plant infested	Larvae and pupae/plant	Larvae and pupae parasitized	% parasitiza-tion	% plant infested	Larvae and pupae/plant	Larvae and pupae parasitized	% parasitiza-tion
December	49	12/5/2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	50	12/12/2007	4.75	2.06b	0.00	0.00	0.00	0.00	0.00	0.00
	51	12/19/2007	4.80	1.97b	0.08a	4.06	0.00	2.15a	0.00	0.00
	52	12/26/2007	4.82	2.11b	0.15a	7.11	0.00	4.56c	0.00	0.00
January	1	1/2/2008	4.85	1.87a	0.37b	19.79	5.25	4.89c	0.06a	1.23
	2	1/9/2008	4.90	1.75a	0.65c	37.14	5.85	4.61c	0.11a	2.39
	3	1/16/2008	5.26	2.15bc	1.33e	61.86	9.80	4.37c	0.43b	9.84
	4	1/23/2008	5.45	2.33cd	0.97d	41.63	13.50	4.07b	0.74c	18.18
	5	1/30/2008	6.09	3.35e	1.06d	31.64	22.43	3.49b	0.55b	15.76
February	6	2/6/2008	6.25	3.29e	1.89h	57.45	22.87	3.75b	0.67c	17.87
	7	2/13/2008	6.85	3.49f	1.50f	42.98	24.81	4.17b	1.03d	24.70
	8	2/20/2008	13.78	3.41e	1.31e	38.42	29.05	4.89c	1.17d	23.93
	9	2/27/2008	18.23	4.11g	1.42e	34.55	32.58	7.65d	1.34e	17.52
March	10	3/5/2008	25.36	4.52h	2.44g	53.98	35.19	13.43e	1.81g	13.48
	11	3/12/2008	28.89	5.65i	3.29h	58.23	37.06	16.49g	2.04h	12.37
	12	3/19/2008	31.90	7.22j	4.50i	62.33	40.11	15.63f	1.97h	12.60
	13	3/26/2008	34.71	9.38k	5.75j	61.30	41.25	20.11h	1.60f	7.96
April	14	4/2/2008	35.00	15.71l	5.90k	37.56	43.19	23.24i	2.30i	9.90
	15	4/9/2008	35.73	19.67m	6.03k	30.66	43.54	25.19j	2.16i	8.57
	16	4/16/2008					46.75	25.25j	2.56j	10.09
	17	4/23/2008					48.05	25.80j	3.22k	12.36
LSD ($P = 0.05$)				0.18	0.13			0.72	0.15	

Table-1.4: population of *P. xylostella* on cabbage at Jalali, Aligarh (October, 2008 to February, 2009)

Months	Std. weeks	Dates (m/d/y)	Var: Fieldman				Var: F1-Deepti			
			% plant infested	Larvae and pupae/plant	Larvae and pupae parasitized	% parasitiza-tion	% plant infested	Larvae and pupae/plant	Larvae and pupae parasitized	% parasitiza-tion
October	40	10/4/2008	0.00	0.00	0.00	0.00	3.48	0.95a	0.08a	8.42
	41	10/11/2008	2.13	0.76a	0.00	0.00	5.66	2.57b	0.21b	8.17
	42	10/18/2008	4.89	1.91b	0.03a	1.57	6.73	3.11c	0.30c	9.65
	43	10/25/2008	6.46	2.34d	0.19bc	8.12	7.82	3.69d	0.73e	19.78
November	44	11/1/2008	7.09	3.02e	0.81i	26.82	8.18	4.60g	0.86f	18.70
	45	11/8/2008	8.37	2.90e	0.78i	26.90	9.47	4.19e	1.23i	29.36
	46	11/15/2008	11.61	5.27k	1.02lm	19.35	12.79	4.05e	1.94l	47.90
	47	11/22/2008	12.31	4.87j	1.47n	30.18	14.47	4.23ef	2.15m	50.83
	48	11/29/2008	13.24	4.09i	0.98l	23.96	14.50	3.92d	2.03l	51.79
December	49	12/6/2008	13.37	3.87h	0.69h	17.83	14.53	4.01e	2.31n	57.61
	50	12/13/2008	13.50	3.50g	0.58g	16.57	14.57	4.25f	1.72k	40.47
	51	12/20/2008	13.62	3.38f	0.91k	26.92	14.60	4.18e	1.68j	40.19
	52	12/27/2008	13.72	3.75h	0.82ij	21.87	15.32	3.85d	1.59j	41.30
January	1	1/3/2009	13.75	3.19f	0.49f	15.36	15.35	3.77d	1.10h	29.18
	2	1/10/2009	14.05	3.60g	0.35e	9.72	15.64	3.81d	1.05g	27.56
	3	1/17/2009	14.09	3.05e	0.28d	9.18	15.70	3.99e	0.96fg	24.06
	4	1/24/2009	14.17	3.55g	0.26d	7.32	15.78	4.15e	0.80e	19.28
	5	1/31/2009	14.20	2.95e	0.18b	6.10	15.80	4.77g	0.45d	9.43
February	6	2/7/2009	14.23	1.85b	0.15b	8.11	15.88	5.29h	0.27b	5.10
	7	2/14/2009	14.45	2.07c	0.22c	10.63	15.90	5.61i	0.21b	3.74
	8	2/21/2009	14.47	1.97b	0.19bc	9.64	16.03	5.73i	0.15a	2.62
	9	2/28/2009						5.79i	0.18ab	3.11
LSD ($P = 0.05$)				0.20	0.04			0.24	0.10	

Table-1.5 : Population of *P. xylostella* on cabbage at Mathura Road, Aligarh (November, 2008 to March, 2009)

Months	Std. weeks	Dates (m/d/y)	Var: Hybrid-1080				Var: Golden Acre			
			% plant infested	Larvae and pupae/plant	Larvae and pupae parasitized	% parasitization	% plant infested	Larvae and pupae/plant	Larvae and pupae parasitized	% parasitization
November	44	11/3/2008	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	45	11/10/2008	3.57	1.28a	0.00	0.00	3.11	1.55c	0.00	0.00
	46	11/17/2008	5.29	4.18g	0.00	0.00	2.40	1.30b	0.12a	9.23
	47	11/24/2008	7.63	3.59f	0.64c	17.83	3.15	1.08a	0.15a	13.89
December	48	12/1/2008	7.65	3.40f	0.61c	17.94	3.50	2.34g	0.17b	7.26
	49	12/8/2008	7.67	3.26e	0.45b	13.80	3.55	2.18f	0.69d	31.65
	50	12/15/2008	7.89	3.19e	1.33f	41.69	3.80	2.15f	0.56c	26.05
	51	12/22/2008	7.90	3.30e	0.67c	20.30	3.85	2.05e	0.95h	46.34
	52	12/29/2008	7.93	3.09e	0.35a	11.33	4.02	1.95de	0.83f	42.56
January	1	1/5/2009	7.99	2.87d	0.95e	33.10	4.05	1.80d	0.75e	41.67
	2	1/12/2009	8.03	3.06e	0.62c	20.26	6.11	3.87j	0.93h	24.03
	3	1/19/2009	8.07	2.75d	0.65c	23.64	6.17	3.50i	0.95h	27.14
	4	1/26/2009	8.11	1.08a	0.95e	87.96	6.15	2.85h	0.78e	27.37
February	5	2/2/2009	8.15	1.45b	0.41a	28.28	7.29	3.75j	0.88g	23.47
	6	2/9/2009	10.07	1.70b	0.35a	20.59	7.46	3.82j	0.67d	17.54
	7	2/16/2009	13.19	2.06c	0.82d	39.81	7.87	4.05k	0.90g	22.22
	8	2/23/2009	15.39	4.53h	0.97e	21.41	8.31	4.67l	0.97hi	20.77
March	9	3/2/2009	19.75	6.11i	1.52g	24.88	10.35	6.97m	1.02j	14.63
	10	3/9/2009	20.47	11.66j	2.38h	20.41	19.04	10.33o	1.33l	12.88
	11	3/16/2009					19.16	10.05n	1.13k	11.24
	12	3/23/2009					22.03	11.23p	1.35l	12.02
	13	3/30/2009					23.18	12.56q	1.44m	11.46
LSD ($P = 0.05$)				0.30	0.08			0.15	0.04	

Table-1.6 : Population of *P. xylostella* on cabbage at G.T. Road, Aligarh (December, 2008 to April, 2009)

Months	Std. weeks	Dates (m/d/y)	Var: Cabbage-NS-25				Var: Diamond Express			
			% plant infested	Larvae and pupae/plant	Larvae and pupae parasitized	% parasitization	% plant infested	Larvae and pupae/plant	Larvae and pupae parasitized	% parasitization
December	48	12/3/2008	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	49	12/10/2008	5.14	2.45a	0.00	0.00	0.00	0.00	0.00	0.00
	50	12/17/2008	5.79	3.35b	0.00	0.00	0.00	0.00	0.00	0.00
	51	12/24/2008	9.67	5.65e	0.00	0.00	4.75	0.00	0.00	0.00
	52	12/31/2008	16.34	5.23d	1.43b	27.34	4.98	2.55a	0.00	0.00
January	1	1/7/2009	21.58	5.49d	1.45b	26.41	7.59	2.49a	0.00	0.00
	2	1/14/2009	22.07	5.17d	2.06c	39.85	12.33	2.67a	0.00	0.00
	3	1/21/2009	25.04	5.07d	2.15c	42.41	15.67	3.11b	0.00	0.00
	4	1/28/2009	25.43	4.87d	1.87c	38.40	19.34	4.89c	2.28a	46.63
February	5	2/4/2009	26.72	2.79a	0.76a	27.24	24.31	4.75c	2.19a	46.11
	6	2/11/2009	26.89	3.04a	1.23b	40.46	24.53	13.62d	3.27c	24.01
	7	2/18/2009	27.04	3.80b	1.89c	49.74	25.72	13.25d	3.55d	26.79
	8	2/25/2009	34.01	4.15c	2.47d	59.52	31.65	17.39e	3.65d	20.99
March	9	3/4/2009	38.46	8.90f	2.55d	28.65	33.46	20.27f	3.18c	15.69
	10	3/11/2009	40.20	15.43g	3.72f	24.11	35.91	23.19g	2.40a	10.35
	11	3/18/2009	42.53	17.91i	3.86f	21.55	39.50	23.64h	2.80b	11.84
	12	3/25/2009	46.67	16.07gh	3.25e	20.22	41.22	24.05hi	3.25c	13.51
April	13	4/1/2009	47.04	22.85j	4.07g	17.81	45.06	23.70h	2.99b	12.62
	14	4/8/2009	47.57	24.13k	4.63h	19.19	46.77	23.50g	3.15c	13.40
	15	4/15/2009					46.85	24.11i	3.70d	13.27
	16	4/22/2009					47.79	24.05hi	3.95e	13.76
	17	4/29/2009					48.19	24.50j	3.28c	13.38
LSD ($P = 0.05$)				0.64	0.33			0.41	0.22	

Table-1.7: Meteorological data of Aligarh from October, 2007 to March, 2008

Months	Std. weeks	Dates (m/d/y)	Max. Temp. (°C)	Min. Temp. (°C)	Avg.Temp. (°C)	Max. R.H. (%)	Min. R.H. (%)	Rainfall (mm)
October	40	10/6/2007	35.07	19.93	27.50	73.00	61.29	
	41	10/13/2007	34.36	17.29	25.83	63.43	59.29	
	42	10/20/2007	32.86	17.21	25.04	75.29	63.14	
	43	10/27/2007	33.29	16.71	25.00	68.43	50.71	
November	44	11/3/2007	31.57	15.07	23.32	70.71	62.57	
	45	11/10/2007	30.29	13.21	21.75	77.14	66.14	
	46	11/17/2007	29.64	13.79	21.72	82.57	63.14	
	47	11/24/2007	27.36	11.79	19.58	82.71	57.57	
December	48	12/1/2007	26.57	11.29	18.93	84.14	64.29	
	49	12/8/2007	23.86	9.93	16.90	83.86	63.57	
	50	12/15/2007	21.64	9.79	15.72	82.29	64.86	
	51	12/22/2007	22.29	6.43	14.36	80.00	53.43	
	52	12/29/2007	22.93	9.07	16.00	67.71	52.14	
January	1	1/5/2008	20.71	4.79	12.75	70.00	53.14	
	2	1/12/2008	23.29	10.36	16.83	79.86	61.57	
	3	1/19/2008	20.86	7.14	14.00	74.86	60.86	
	4	1/26/2008	23.93	9.50	16.72	68.00	55.29	
February	5	2/2/2008	18.14	5.79	11.97	65.43	52.57	0.50
	6	2/9/2008	19.07	8.50	13.79	80.14	68.29	11.60
	7	2/16/2008	21.79	5.43	13.61	69.14	55.71	
	8	2/23/2008	26.07	10.79	18.43	67.29	58.57	
March	9	1/3/2008	27.29	10.93	19.11	67.29	59.29	

Table-1.8:Meteorological data of Aligarh from November, 2007 to March, 2008

Months	Std. weeks	Dates (m/d/y)	Max. Temp. (°C)	Min. Temp. (°C)	Avg.Temp. (°C)	Max. R.H. (%)	Min. R.H. (%)	Rainfall (mm)
November	45	11/5/2007	31.21	14.07	22.64	73.57	63.14	
	46	11/12/2007	30.21	13.43	21.82	81.00	65.43	
	47	11/19/2007	28.79	16.07	22.43	82.71	60.00	
	48	11/26/2007	27.39	11.36	19.38	83.57	61.00	
December	49	12/3/2007	25.79	11.79	18.79	84.86	64.00	
	50	12/10/2007	23.14	8.69	15.92	80.29	64.00	
	51	12/17/2007	21.36	8.93	15.15	85.00	60.43	
	52	12/24/2007	22.93	8.29	15.61	75.86	55.00	
	53	12/31/2007	22.14	7.14	14.64	67.29	51.00	
January	1	1/7/2008	21.50	6.07	13.79	71.00	55.00	
	2	1/14/2008	22.21	9.50	15.86	80.29	60.29	
	3	1/21/2008	20.29	8.64	14.47	72.43	63.29	
	4	1/28/2008	17.36	4.57	10.97	66.00	53.29	
February	5	2/4/2008	18.93	6.21	12.57	69.14	56.14	
	6	2/11/2008	19.21	7.21	13.21	80.00	66.29	0.50
	7	2/18/2008	23.50	7.00	15.25	66.71	54.14	11.60
	8	2/25/2008	26.00	11.29	18.65	69.00	61.14	
March	9	3/3/2008	29.29	11.93	20.61	66.71	57.43	
	10	3/10/2008	31.50	16.29	23.9	78.57	56.43	
	11	3/17/2008	29.79	15.64	22.72	71.71	60.86	0.60
	12	3/24/2008	33.36	16.71	25.04	69.43	62.71	0.80
	13	3/31/2008	34.79	18.14	26.47	63.14	54.29	

Max. = Maximum,
Min. = Minimum,
Avg. = Average
Temp. = Temperature,
R.H. = Relative humidity
mm. = milimeter

Table-1.9: Meteorological data of Aligarh from December, 2007 to April, 2008

Months	Std. weeks	Dates (m/d/y)	Max. Temp. (°C)	Min. Temp. (°C)	Avg.Temp. (°C)	Max. R.H. (%)	Min. R.H. (%)	Rainfall (mm)
December	49	12/5/2007	25.07	11.21	18.14	79.71	65.29	
	50	12/12/2007	22.36	9.36	15.86	79.86	67.00	
	51	12/19/2007	21.21	7.14	14.18	82.57	54.57	
	52	12/26/2007	23.93	9.50	16.72	74.86	54.29	
January	1	1/2/2008	20.79	5.50	13.15	66.14	52.86	
	2	1/9/2008	23.21	8.29	15.75	75.57	56.57	
	3	1/16/2008	21.29	8.64	14.97	76.57	60.00	
	4	1/23/2008	18.29	7.07	12.68	73.43	61.71	
	5	1/30/2008	18.29	5.14	11.72	61.43	50.57	
February	6	2/6/2008	18.86	7.14	13.00	78.43	64.29	
	7	2/13/2008	19.86	5.93	12.90	73.86	59.71	0.40
	8	2/20/2008	24.79	8.43	16.61	65.29	56.14	11.60
	9	2/27/2008	26.14	11.36	18.75	68.43	61.00	
March	10	3/5/2008	31.07	13.64	22.36	72.43	55.71	
	11	3/12/2008	30.29	16.57	23.43	77.57	60.71	
	12	3/19/2008	32.00	16.21	24.11	68.43	59.14	0.50
	13	3/26/2008	32.86	16.14	24.50	69.57	61.29	0.60
April	14	4/2/2008	34.36	18.79	26.58	63.93	56.07	
	15	4/9/2008	30.36	17.29	23.83	75.57	65.29	9.60
	16	4/16/2008	37.71	21.36	29.54	57.71	52.57	
	17	4/23/2008	38.93	20.64	29.79	48.86	42.29	

Table-1.10: Meteorological data of Aligarh from October, 2008 to February, 2009

Months	Std. weeks	Dates (m/d/y)	Max. Temp. (°C)	Min. Temp. (°C)	Avg.Temp. (°C)	Max. R.H. (%)	Min. R.H. (%)	Rainfall (mm)
October	40	10/4/2008	35.21	25.14	30.18	73.14	53.14	
	41	10/11/2008	35.86	23.5	29.68	73.86	43.29	
	42	10/18/2008	33.93	21.21	27.57	71.86	39.14	
	43	10/25/2008	32.86	18.43	25.65	72.00	32.43	
November	44	11/1/2008	32.36	17.79	25.08	78.57	33.43	
	45	11/8/2008	31.71	15.43	23.57	71.29	31.29	
	46	11/15/2008	29.86	15.00	22.43	82.29	44.86	
	47	11/22/2008	27.14	14.50	20.82	84.29	44.57	6.60
	48	11/29/2008	26.43	10.86	18.65	84.14	41.43	
December	49	12/6/2008	26.14	11.29	18.72	84.14	43.14	
	50	12/13/2008	25.36	12.50	18.93	85.57	48.29	
	51	12/20/2008	24.00	11.71	17.86	81.14	51.00	
	52	12/27/2008	22.14	9.50	15.82	86.57	48.86	
January	1	1/3/2009	18.86	7.64	13.25	94.14	65.71	
	2	1/10/2009	19.29	7.36	13.33	89.14	64.86	
	3	1/17/2009	22.43	9.57	16.00	89.71	48.43	
	4	1/24/2009	23.14	10.86	17.00	85.43	53.14	
	5	1/31/2009	24.43	10.86	17.65	90.71	50.00	
February	6	2/7/2009	25.64	10.86	18.25	86.43	44.86	
	7	2/14/2009	24.07	10.79	17.43	88.29	50.29	3.20
	8	2/21/2009	26.07	10.71	18.39	83.57	41.57	
	9	2/28/2009	28.57	13.43	21.00	76.71	30.43	

Table-1.11: Meteorological data of Aligarh from November, 2008 to March, 2009

Months	Std. weeks	Dates (m/d/y)	Max. Temp. (°C)	Min. Temp. (°C)	Avg.Temp. (°C)	Max. R.H. (%)	Min. R.H. (%)	Rainfall (mm)
November	44	11/3/2008	32.50	17.29	24.90	73.71	33.00	
	45	11/10/2008	31.14	15.14	23.14	75.00	36.14	
	46	11/17/2008	29.21	14.71	21.96	81.71	42.00	
	47	11/24/2008	26.07	13.50	19.79	84.86	45.57	6.6
December	48	12/1/2008	26.43	10.79	18.61	86.14	43.86	
	49	12/8/2008	26.42	11.93	19.18	82.43	44.43	
	50	12/15/2008	24.93	11.36	18.15	83.43	44.14	
	51	12/22/2008	23.43	12.93	18.18	84.29	53.86	
	52	12/29/2008	22.50	8.36	15.43	88.57	51.00	
January	1	1/5/2009	17.00	7.14	12.07	94.29	70.00	
	2	1/12/2009	20.71	7.50	14.11	88.86	59.43	
	3	1/19/2009	22.93	11.00	16.97	90.00	51.00	
	4	1/26/2009	23.50	10.79	17.15	85.71	51.43	
February	5	2/2/2009	24.07	9.86	16.97	88.00	48.57	
	6	2/9/2009	26.29	11.07	18.68	86.43	40.29	
	7	2/16/2009	23.86	11.00	17.43	87.71	53.86	3.20
	8	2/23/2009	27.36	11.71	19.54	82.43	38.00	
March	9	3/2/2009	28.50	13.00	20.75	66.43	29.43	
	10	3/9/2009	31.79	15.07	23.43	72.00	32.71	
	11	3/16/2009	31.50	14.00	22.75	60.00	32.29	
	12	3/23/2009	32.50	17.21	24.86	67.86	33.14	
	13	3/30/2009	32.36	17.57	24.97	64.71	33.00	1.8

Table-1.12: Meteorological data of Aligarh from December, 2008 to April, 2009

Months	Std. weeks	Dates (m/d/y)	Max. Temp. (°C)	Min. Temp. (°C)	Avg.Temp. (°C)	Max. R.H. (%)	Min. R.H. (%)	Rainfall (mm)
December	48	12/3/2008	26.07	11.07	18.57	86.71	46.43	
	49	12/10/2008	26.57	12.36	19.47	83.14	43.00	
	50	12/17/2008	24.50	10.50	17.50	83.00	45.00	
	51	12/24/2008	22.57	12.50	17.54	82.57	52.71	
	52	12/31/2008	21.79	8.07	14.93	92.43	55.14	
January	1	1/7/2009	16.86	6.93	11.90	94.00	73.14	
	2	1/14/2009	21.64	8.14	14.89	88.86	52.29	
	3	1/21/2009	22.36	10.86	16.61	88.71	54.57	
	4	1/28/2009	24.71	11.36	18.04	85.86	49.00	
February	5	2/4/2009	24.50	9.57	17.04	88.00	46.71	
	6	2/11/2009	24.93	11.71	18.32	86.00	45.71	3.20
	7	2/18/2009	24.71	10.36	17.54	87.14	48.14	
	8	2/25/2009	28.64	13.07	20.86	80.00	36.29	
March	9	3/4/2009	29.43	13.43	21.43	67.29	29.43	
	10	3/11/2009	31.43	14.29	22.86	65.00	30.86	
	11	3/18/2009	32.14	14.79	23.47	63.29	32.86	
	12	3/25/2009	32.64	18.00	25.32	65.14	32.86	0.80
April	13	4/1/2009	32.21	17.21	24.71	66.29	32.57	2.80
	14	4/8/2009	35.00	19.07	27.04	58.43	32.00	12.00
	15	4/15/2009	36.21	18.71	27.46	48.29	25.71	
	16	4/22/2009	39.86	23.29	31.58	31.86	15.00	
	17	4/29/2009	40.43	22.21	31.32	25.43	11.86	

Table-1.13: Correlation between abiotic factors and *P. xylostella* and its parasites (2007-08)

Variety	Max.Temp.		Min.Temp.		Avg.Temp.		Max. R.H.		Min. R.H.		Rainfall	
	A	B	A	B	A	B	A	B	A	B	A	B
Field Man	-0.62**	-0.79**	-0.67**	-0.82**	-0.65**	-0.82**	-0.08	-0.07	0.13	-0.01	0.22	0.18
F1-Deepti	0.12	-0.18	0.07	-0.20	0.10	-0.19	0.47*	0.71**	0.35	0.11	-0.18	-0.25
Hybrid-1080	0.41	-0.19	0.44	-0.11	0.43	-0.15	-0.23	-0.16	-0.16	-0.28	0.01	-0.09
Golden Acre	0.58**	-0.14	0.61**	-0.13	0.60**	-0.14	-0.42*	-0.57**	-0.15	-0.43*	-0.02	0.15
Cabbage-NS-25	0.69**	0.79**	0.76**	0.84**	0.73**	0.73**	-0.27	-0.32	0.17	0.18	0.42	0.27
Diamond Express	0.90**	0.86**	0.92**	0.87**	0.92**	0.87**	-0.57**	-0.64**	-0.29	-0.32	0.15	0.17

Table-1.14: Correlation between abiotic factors and *P. xylostella* and its parasites (2008-09)

Variety	Max.Temp.		Min.Temp.		Avg.Temp.		Max.R.H.		Min.R.H.		Rainfall	
	A	B	A	B	A	B	A	B	A	B	A	B
Field Man	-0.48*	-0.17	-0.57**	-0.25	-0.53*	-0.21	0.44*	0.13	0.07	-0.14	0.35	0.44*
F1-Deepti	-0.42	-0.29	-0.62**	-0.33	-0.53*	-0.31	0.39	0.25	-0.24	0.08	0.02	0.21
Hybrid-1080	0.27	0.01	0.18	-0.04	0.24	-0.01	-0.43	-0.29	-0.32	0.13	-0.03	-0.01
Golden Acre	0.52*	0.33	0.44*	0.32	0.50*	0.33	-0.72**	-0.54*	-0.52*	-0.30	-0.06	-0.27
Cabbage-NS-25	0.77**	0.70**	0.82**	0.67**	0.80**	0.70**	-0.87**	-0.77**	-0.62**	-0.58**	0.60**	0.49*
Diamond Express	0.85**	0.73**	0.81**	0.68**	0.84**	0.71**	-0.80**	-0.64**	-0.82**	-0.73**	0.31	0.25

A= Larvae and pupae/plant B= Larvae and pupae parasitized * Significant at 0.05 level ** Significant at 0.01 level
Max. = Maximum Min. = Minimum Avg. = Average Temp. = Temperature
R.H. = Relative humidity

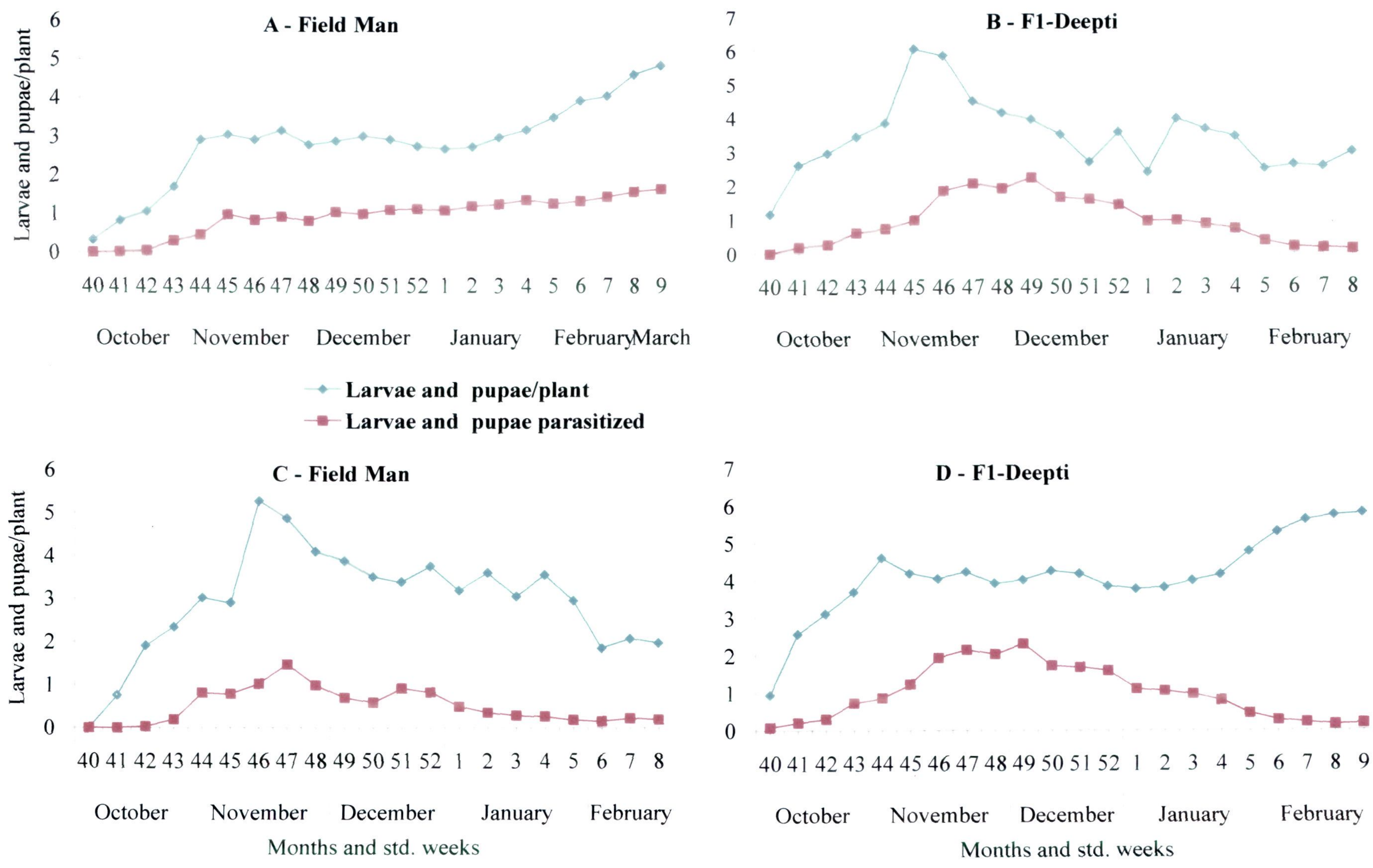


Fig.1.1- Population of *P. xylostella* and its parasites on cabbage at Jalali. A & B (2007-08), C & D (2008-09)

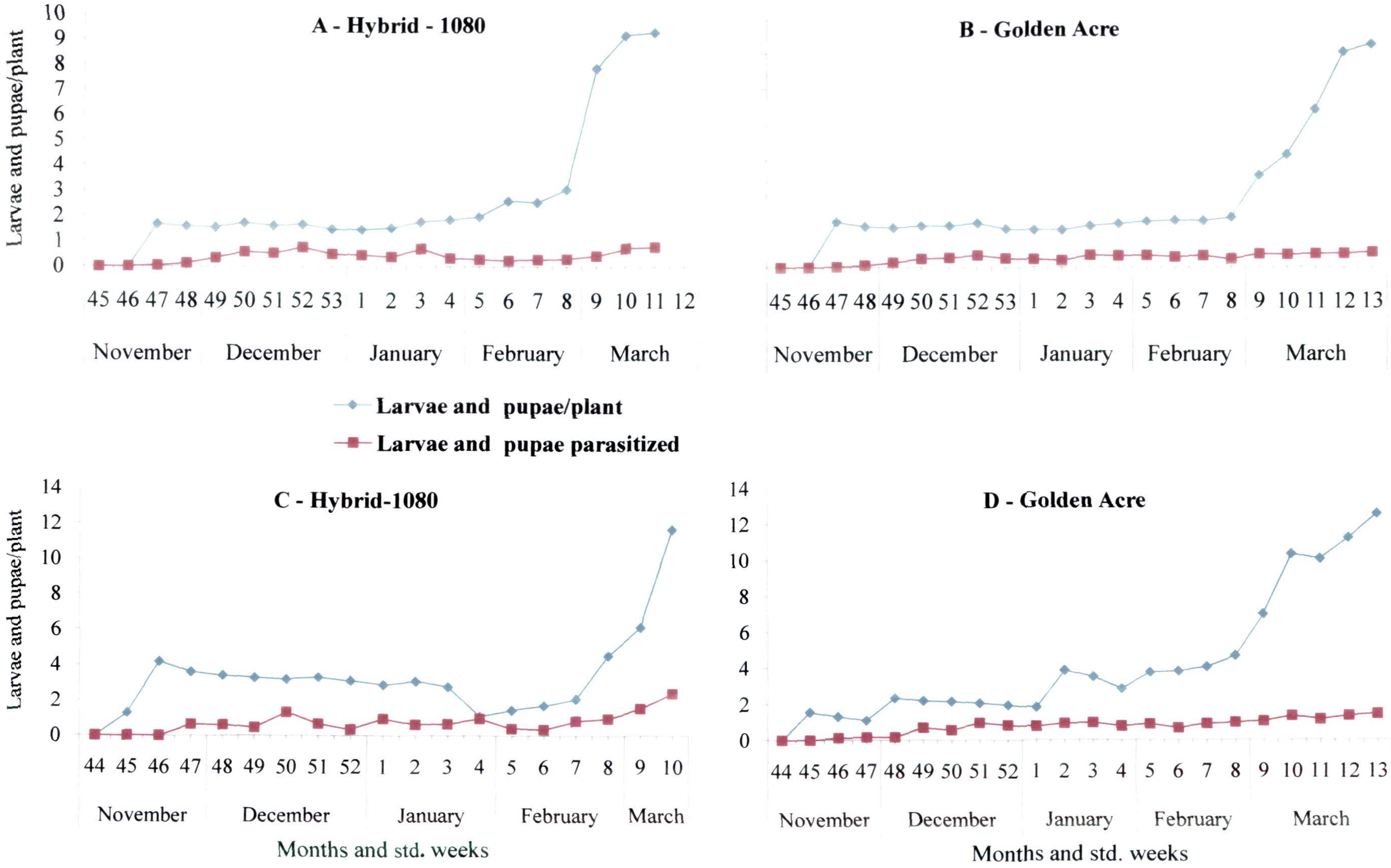


Fig.1.2- Population of *P. xylostella* and its parasites on cabbage at Mathura Road. A & B (2007-08), C & D (2008-09)

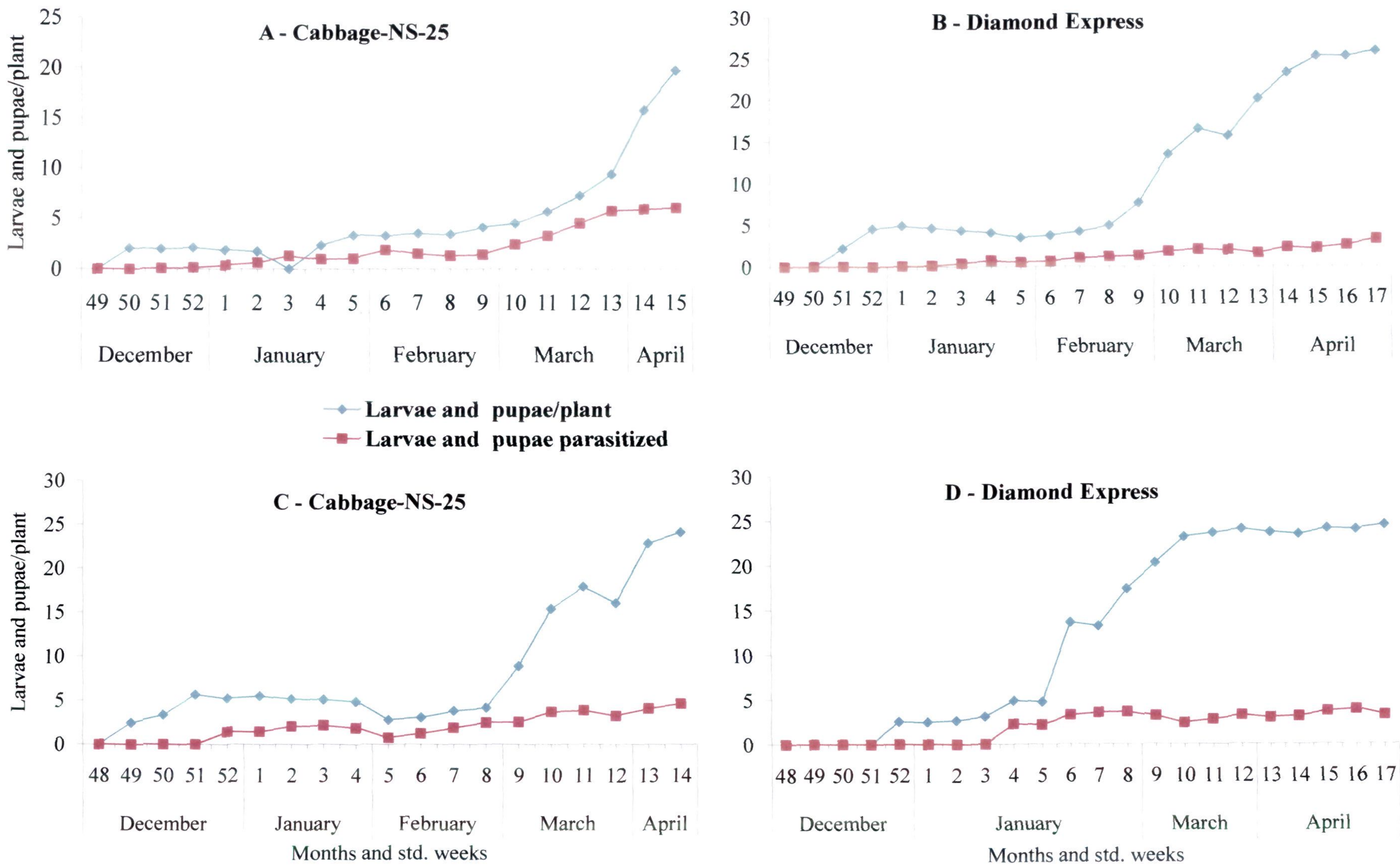


Fig.1.3- Population of *P. xylostella* and its parasites on cabbage at G.T. Road. A & B (2007-08), C & D (2008-09)

2. Studies on oviposition, feeding behavior and larval survival of *P. xylostella* on *Brassica* hosts:

A. Oviposition behavior of *P. xylostella* on *Brassica* hosts:

Analyzed result (Table-2.1, Fig. 2.1) showed that female of *P. xylostella* is significantly preferred to oviposit on cabbage as compared to Indian mustard in both choice and no-choice tests. While, Diamond Express of cabbage was more preferred host followed by Hybrid-1080, Golden Acre, F1-Deepti and Field Man in both choice and no-choice tests. Pusa Bold of Indian mustard is more preferred over Varuna and Pusa Bahar in both choice and no-choice tests. Eggs laid by *P. xylostella* were statistically same on Indian mustard varieties in choice and no choice test of 2007-08 and 2008-09. However, number of eggs laid by *P. xylostella* was similar on F1-Deepti and Field Man in both choice and no-choice tests in 2007-08. Hybrid-1080 and Diamond Express were significantly different in both choice and no-choice tests in both years of study. The number of eggs laid by female of *P. xylostella* on cabbage varieties was significantly differed in choice test whereas; F1-Deepti and Golden Acre were similar in no-choice test in 2008-09 (Table-2.1). Average number of eggs /5females ranged between 14.25 to 16.25 and 109.27 to 138.20 in both choice and no-choice tests, respectively on Indian mustard varieties which were significantly similar during both years, but significantly ($P<0.05$) differed ranged from 25.01 to 73.31 in choice test on cabbage varieties. 204.09 to 623.66 eggs/5 females were ranged on cabbage varieties in no choice test, while F1-Deepti and Field Man were same but rest of the four varieties were significantly differed in no-choice test in mean of both years (Table-2.2). Therefore, cabbage varieties are more preferred for oviposition by female of *P. xylostella* because leaves are glossy than to hairy/spiny leaves of Indian mustard varieties. Number of eggs laid by females of *P. xylostella* were 8.5, 8.0, 7.4, 8.16, 7.94, 8.62, 8.5, 7.66 and 8.09 times greater in no-choice than choice tests on Diamond Express, Hybrid-1080, F1-Deepti, Field Man, Golden Acre, cabbage-NS-25, Pusa Bold, Varuna and Pusa Bahar, respectively.

B. Feeding behavior of *P. xylostella* on *Brassica* hosts:

Feeding behavior of larvae of *P. xylostella* was significantly/non significantly differed on cabbage and Indian mustard in both choice and no-choice tests during 2007-08 and 2008-09 (Table-2.3 and Fig. 2.2-2.3). The highest leaf area consumed by the larva of *P. xylostella* was i.e. 15.05, 15.77 cm^2 and 14.97, 15.94 cm^2 and the lowest i.e. 6.21, 7.59

cm^2 and 6.03, 8.83 cm^2 on Diamond Express and Field Man in both choice and no-choice tests during 2007-08 and 2008-09, respectively. Whereas, feeding was statistically similar in Indian mustard varieties in both tests during both years, respectively. Hybrid-1080 and Cabbage-NS-25 were found similar, but other four varieties were significantly differed in both tests in 2007-08. F1-Deepti and Field Man were statistically similar, Cabbage-NS-25 and Golden Acre were also recorded similar in no-choice test in 2008-09. It is concluded that Diamond Express is highly preferred/susceptible variety of cabbage for *P. xylostella* followed by Hybrid-1080, Cabbage-NS-25, Golden Acre, F1-Deepti and Field Man. Whereas, larva of *P. xylostella* preferred to feed more on Pusa Bold than Varuna and Pusa Bahar of Indian mustard in both tests during both years of study. Diamond Express was significantly ($P<0.05$) preferred variety of cabbage for feeding by larvae of *P. xylostella* being most susceptible and Field Man was least preferred variety being most resistant in both choice and no-choice tests during both years. It is concluded that light green colour of cabbage leaves (Diamond Express, Hybrid-1080 and Cabbage-NS-25) are more preferred by female of *P. xylostella* than green and dark green (F1-Deepti, Golden Acre and Field Man) leaves.

C. Larval survival of *P. xylostella* on *Brassica* hosts:

a. In protected field condition:

Brassica hosts: 3 cabbage varieties i.e. Field Man, Golden Acre, Diamond Express and 3 Indian mustard; Pusa Bold, Varuna and Pusa Bahar bearing the eggs of *P. xylostella* were kept under protected condition for hatching. 100 eggs on each variety was selected and marked. Larval survival was recorded daily from the day of hatching of egg to formation of pre-pupal stage. Result (Table-2.4 Fig. 2.4) showed that larval survival was found to be highest i.e. 80.58 and 82.76 percent on Diamond Express and smallest on Pusa Bahar i.e. 30.84 and 47.76 percent in 2007-08 in both choice and no-choice tests, respectively. Whereas, it was 83.12 and 81.06 percent on Diamond Express and least i.e. 33.39 and 49.26 percent on Pusa Bahar in both tests, respectively in 2008-09 (Table2.5 Fig. 2.5). However, larval survival was not significantly different on Golden Acre and Diamond Express i.e. 79.30 and 80.58 percent, respectively in choice test and 76.19 and 82.76 percent, respectively in no-choice test in 2007-08. The lowest survival was on Field Man (40.37 and 50.24 percent) and (39.53 and 54.15 percent) in choice and no-choice tests, respectively during both years of study. Among the Indian mustard, larval survival was highest (35.23, 56.24 percent) and 41.68 and 53.47 percent on Pusa Bold and least on Pusa Bahar, respectively.

b. At constant temperatures:

Larval survival of *P. xylostella* is considerably affected by *Brassica* hosts at constant temperatures. Larval survival (Table-2.6, Fig.2.6-2.10) was highest on Diamond Express and the lowest on Field Man on cabbage at all temperatures tested. Among the Indian mustard, survival of larvae was greater on Pusa Bahar at 20°C in comparison to Pusa Bold and Varuna. Larval survival was smaller (12.88 percent) on Pusa Bahar than that of Varuna and Pusa Bold at 10°C (Table 2.6, Fig. 2.6). Increasing the temperature from 10° to 20°C, larval survival was also increased and then decreased from 20° to 30°C (Table 2.6, Fig. 2.7). Further, larval survival was higher on *Brassica* hosts at 20°C except Varuna which inflicted more larval mortality than Pusa Bold and Pusa Bahar (Table 2.6, Fig. 2.8). Larval survival was less on Pusa Bahar at 25°C in comparison to Pusa Bold and Varuna. Larval survival was reduced at 30°C in on all *Brassica* hosts (Table 2.6, Fig. 2.10). Larval survival was higher at 20° and 25°C on cabbage and Indian mustard varieties as compared to other temperatures.

Uematsu and Sakanoshita (1989) suggested that cabbage leaves are basically attractive to ovipositing females of *P. xylostella*, however, the wax bloom on leaves suppresses oviposition and decreases the adhesiveness of eggs. Renwick and Radke (1990) studied oviposition by *P. xylostella* and *P. rapae* on various host plants which showed that despite the similarity in their host ranges, different chemical cues were probably involved in the acceptance or rejection of potential hosts. *P. xylostella* was shown to depend largely on the presence of stimulatory compounds and was not affected by deterrents that caused avoidance of plants in *P. rapae*. Host plant chemical cues have a great effect on ditrophic interactions (Vet and Dicke,1992). The difference in egg laying on different host plants demonstrated that chemical cues mediated host plant selection in *P. xylostella* females emerges on larvae reared on canola laid significantly higher number of eggs as compared with females from larvae emerged from other host plants. The variation in *P. xylostella* has previously been shown to be associated with host plants and the condition under which the plants were grown (Lu *et al.*, 2004, Badenes-Perez *et al.*, 2005). Talekar *et al.* (1994) examined the oviposition behaviour of *P. xylostella* and observed that females lay eggs mainly on outer leaves of cabbage plant. On outer leaves, eggs were laid mainly on the upper leaf surface: on inner leaves they were laid on the lower leaf surface. Egg density decreased from outer to inner leaves. Within a range of 1-11 trichomes/9 mm^2 leaf area, the number of eggs laid on Chinese cabbage leaves increased with trichome density. Most oviposition activity took place within two hours after sunset this period coincides with maximum mating related flying activity. During daylight hours when the plutellid does not normally lay eggs initiation of darkness stimulated oviposition. However, during the night when the pest normally lays eggs artificial light did not reduce oviposition activity. Reddy *et al.* (2004) concluded that oviposition by female *P. xylostella* did not differ significantly among the tested *Brassica* hosts i.e. cabbage, cauliflower, kohlrabi and broccoli in no-choice tests. Whereas, in free-choice tests, oviposition by DBM was significantly greater on cabbage followed by cauliflower, broccoli and kohlrabi. Pivnik *et al.* (1994) found that females of *P. xylostella* preferred to oviposit on cabbage, cauliflower, broccoli and kohlrabi. Badenes-Perez *et al.,* (2004) evaluated trap crop through a series of ovipositional preference. In a choice tests, number of eggs laid on glossy collards, Indian mustard, and yellow rocket were 3, 18 and 12 times greater than on cabbage, respectively. Similarly in no-choice tests, number of eggs laid on glossy collards, Indian mustard, and yellow rocket were 300, 19, and 110 times greater than on cabbage, respectively. Present studies showed that 7 to 9 times more eggs were laid on *B. oleracea* hosts by the females of *P. xylostella* in no-choice tests than choice one than Indian mustard. Musser *et al.* (2005) planted the Glossy-leaved collards, *B. oleracea* L. var. *acephala* as a trap crop in cabbage field, which are attractive to *P. xylostella* adults and are poor host for *P. xylostella* larvae compared to cabbage. Furthermore, they planted the trap crop in dispersed and concentrated spatial arrangements to determine the impact of trap crop arrangement on the behavior of *P. xylostella.* Results showed that presence of collards within a cabbage field reduced larval density on cabbage in the first year but in the subsequent year, trap crop had an insignificant impact on larval density of *P. xylostella* on cabbage. Eggs and larval data showed that total oviposition was highest near a central release point in both years in all treatments, indicating that females laid many eggs before dispersing very far when suitable host plants were available. The mean direction of *P. xylostella* movement and oviposition from a central release point was not consistent or correlated to wind direction.

Ahmad *et al.* (2008) reported that females prefer to lay eggs on *B. napus* because of hairy and glossy leaf surface as compared to *B. juncea* where leaf surface is hairy and spiny. Glossy leaves have reduced wax load (Andrahennadi and Gillott, 1998, Stoner, 1992, Eigenbrode and Shelton, 1992). Similarly preference of diamondback moth oviposition for glossy plants has also been shown in *B. oleracea* (Lin *et al.,* 1983), *B. napus* (Justus *et al.,* 2000) and *Barbarea vulgaris* (Shelton and Nault, 2004). Idris and Grafius (1996) reported that oviposition by *P. xylostella* was highest on the *Brassica* crops, especially broccoli and lowest on wild *Brassica* especially *Berteroa incana* and *Erysimum cheiranthoides*. GuoQuan *et al.* (1998) also found that female of *P. xylostella* preferred to lay their eggs on Indian mustard (*B. juncea*) and flowering Chinese cabbage (*B. parachinensis*) as compared with radish (*R. sativus*), Chinese kale (*B. alboglabra*) and cauliflower (*B olaracea* var. *botrytis*). Indian mustard was used as a trap crop and showed that Chinese kale cultivated at intervals of 5-10 m with paired Indian mustard rows could decrease the population of *P. xylostella* and reduced insecticide application. Laboratory studies of Charleston and Kfir (2000) revealed that *P. xylostella* preferred to lay highest number of eggs on Indian mustard in comparison to cabbage, cauliflower and broccoli. In present study contrary result obtained that highest number of eggs were laid by females of *P. xylostella* on cabbage varieties than Indian mustard. Females emerged from the larvae reared on canola laid significantly higher number of eggs as compared with females reared on cauliflower, cabbage, mustard, turnip and radish (Saeed *et al.*, 2010). Begum *et al.* (1996) reported that females of *P. xylostella* reared on wild canola were less fecund as compared with those reared on canola grown in laboratory. Hamilton *et al.* (2005) reported that there were no differences in the number of eggs laid on the various cultivars of broccoli or cauliflower. Significantly more eggs were laid on cabbage cultivar, Savoy king than any of other cabbage cultivars tested. Sarfaraz *et al.* (2007) found that females laid 2.8, 4.2 and 14.8 fold more eggs on *Sinapis alba* than *B. napus* Q2, *B. napus* conquest and *B. olaraceae,* respectively. *B. juncea*, *B. napus* Liberty and *B carinata* plants received 1.5, 1.6 and 1.9 fold fewer eggs, respectively than *S. alba*.

Dickson and Eckenrode (1975) and Stoner (1990) reported that the dark green glossy lines are comparatively more resistant than light green normal leaves. Baker (1974) and Jeffree *et al.* (1976) have reported that the dark green and glossy appearance is due to change in the structure of wax on the leaf surface. The light green category was noticed to be most susceptible which confirm the finding of the present studies.

Hamilton *et al.* (2005) studied the larval feeding of *P. xylostella* on four cultivars of *B. olaracea* vegetables. They reported that larvae developed more rapidly and fed more and for longer on green coronet than Savoy king. Akhtar and Isman (2003) reported larval feeding experience on subsequent oviposition behaviour of adult moths of *Trichoplusia ni* and *P. xylostella*. Both lay eggs singly, mostly on the lower surface of leaves. Larval feeding was significantly ($P<0.05$) higher on all the varieties of cabbage than Indian mustard in both the tests during both years. Sarfaraz *et al.* (2007) reported that host plants had significant effect on foliage consumption by individual female and male larvae. They consumed largest area of leaves of *B. rapa* while male larvae had least foliage consumption on *B. napus* Liberty. Almost similar results obtained by Ansari *et al.* (2010) that larval feeding was significantly ($P<0.05$) more on cabbage (control) than Pusa Bold, Varuna and Pusa Bahar in a non-option test and 25°C was the most conducive temperature for feeding of larvae of *P. xylostella* as compared with 20°C, 15°C and 10°C. This finding is closely related with that of the present findings.

Larval survival of *P. xylostella* was higher at 20° and 25°C on *Brassica* hosts and reduced at 30°C in the present study. Survival rate from egg to emergence was 56, 72 and 13 % at 20, 25 and 30°C, respectively (Chung *et al.* 1989). According to Liu *et al.* (2002) the survival rate of *P. xylostella* from egg to adult emergence were 19.2, 76.1, 73.7 and 50.9% at 10, 20, 28 and 30°C, respectively on cabbage. While, Golizadeh *et al.* (2009) showed that the survival rates were 58.3, 86.2, 77.6 and 72.2% at 10, 15, 20, 25, 28 and 30°C, respectively on cabbage. Higher survival rates can be attributed to the cultivars of host plants, host plant ages and strains of *P. xylostella* (Umeya and Yamada, 1973, Liu *et al.*, 1985, Sarnthoy *et al.*, 1989, Shirai, 2000) but insect survival did not differ among the Brassicaceae plants (Sarfraz *et al.*, 2007). Charleston and Kfir (2000) observed that mean percentage survival was highest on cabbage (70%) followed by broccoli (67%), cauliflower (58%) and finally Indian mustard. Badenes-Perez *et al.* (2004) reported that *P. xylostella* prefers to oviposit on the glossy variety of collard, *B. oleracea* var. *acephala* up to 300 times more than cabbage, but the percentage larval survival from egg to pupation was 22.20 on cabbage, 18.90 on waxy collards, and 24.40 on Indian mustard. Larval survival of *P. xylostella* has been shown to be higher on younger than older leaves of cabbage collard (Badenes-Perez *et al.*, 2005a) and no larvae survival on *B. vulgaris* regardless of age. Where, saponins acting as feeding deterrent responsible for lack of survival of *P. xylostella* larvae on *B. vulgaris* (Shinoda *et al.*, 2002, Agerbirk *et al.*, 2003). Stoner (1990) found that larval survival was low on glossy variety of cabbage. Larval survival was reduced on *B. rapa* (Barker and Maczka, 1996) while the larvae of *P. xylostella* did not survive on *B. vulgaris* but females preferred to lay eggs (Idris and Grafius, 1996). Larval survival of *P. xylostella* was lower on glossy plants than on the other *B. rapa* and 56.3 percent on *B. napus* (Ulmer *et al.,* 2002). Saeed *et al.* (2010) found that larvae of *P. xylostella* fed on turnip (*B. rapa*) had considerably reduced survival rates as compared to cauliflower, cabbage, mustard, canola and radish and it was due to heavy early instar mortality and unsuitability of the host plant and larval host plants can have a significant effect on both adult longevity and fecundity. In the present study, it is also observed that comparatively more larval survival was recorded on light green cabbage leaves (Diamond Express) than dark green (Golden Acre) as mentioned earlier.

Table-2.1: Oviposition behaviour of *P. xylostella* on *Brassica* varieties

Host plants	Choice Test*	No-choice Test**
	2007-08	
Diamond Express	78.36±2.31f	678.86±17.32f
Hybrid-1080	68.49±2.31e	537.57±14.43e
F1-Deepti	29.08±1.73b	212.35±6.93c
Field Man	24.83±1.15b	198.45±4.62c
Golden Acre	33.93±1.73c	292.63±6.93d
Cabbage-NS-25	57.56±1.48d	515.04±8.66e
Pusa Bold	17.67±0.96a	155.47±4.33b
Varuna	14.94±0.58a	119.67±3.46a
Pusa Bahar	16.56±0.58a	138.77±4.62a
LSD (P=0.05)	4.83	30.57
	2008-09	
Diamond Express	68.26±1.73g	568.45±15.59f
Hybrid-1080	61.99±1.73f	504.33±14.43e
F1-Deepti	32.57±1.48c	245.09±6.93c
Field Man	25.19±0.69b	209.73±5.20b
Golden Acre	36.63±0.94d	267.47±1.73c
Cabbage-NS-25	53.03±1.73e	438.55±12.70d
Pusa Bold	14.82±0.47a	120.92±3.46a
Varuna	13.56±0.32a	98.87±2.81a
Pusa Bahar	14.16±0.43a	109.66±3.27a
LSD (P=0.05)	3.46	25.38

Table-2.2: Oviposition of *P. xylostella* on *Brassica* hosts

	2007-08 & 2008-09 (Pooled mean)	
Host plants	Choice Test*	No-choice Test**
Diamond Express	73.31±2.17g	623.66±18.03f
Hybrid-1080	65.24±1.87f	520.95±15.10e
F1-Deepti	30.83±0.89c	228.72±6.64b
Field Man	25.01±0.72b	204.09±5.91b
Golden Acre	35.28±1.02d	280.05±8.08c
Cabbage-NS-25	55.30±1.61e	476.8±13.74d
Pusa Bold	16.25±0.47a	138.2±4.04a
Varuna	14.25±0.42a	109.27±3.16a
Pusa Bahar	15.36±0.45a	124.22±3.59a
LSD (P=0.05)	3.83	30.52

Similar alphabets are non significant at 0.05 level

* Mean of five replicates

** Mean of ten replicates

Table-2.3: Feeding behaviour of larvae of *P. xylostella* on *Brassica* hosts under protected field condition

				2007-08				
Hosts	II	III	IV	Total (cm^2)	II	III	IV	Total (cm^2)
	Choice *				No-choice **			
Diamond Express	3.87±0.09	5.45±0.16	5.73±0.17	15.05f	4.07±0.09	5.65±0.16	6.05±0.18	15.77f
Hybrid-1080	3.18±0.07	4.87±0.14	5.04±0.14	13.09e	3.65±0.08	3.91±0.08	4.25±0.12	11.81e
F1-Deepti	1.84±0.02	2.35±0.03	3.12±0.06	7.31c	2.49±0.04	2.76±0.05	3.47±0.08	8.72c
Field Man	1.37±0.01	2.09±0.03	2.75±0.05	6.21b	2.03±0.03	2.27±0.04	3.29±0.08	7.59b
Cabbage-NS-25	3.07±0.05	4.52±0.12	5.21±0.12	12.80e	3.45±0.08	3.58±0.08	4.23±0.11	11.26e
Golden Acre	2.77±0.04	3.55±0.06	4.09±0.09	10.41d	3.17±0.07	3.78±0.09	4.05±0.12	11.00d
Pusa Bold	0.87±0.006	1.23±0.01	1.38±0.03	3.48a	1.27±0.02	1.32±0.02	2.45±0.06	5.04a
Varuna	0.71±0.006	1.15±0.01	1.27±0.02	3.13a	1.21±0.02	1.25±0.02	2.56±0.07	5.02a
Pusa Bahar	0.68±0.006	0.95±0.01	1.19±0.01	2.82a	1.08±0.01	1.19±0.02	2.11±0.05	4.38a
P=0.05				1.00				1.04
				2008-09				
Hosts	II	III	IV	Total (cm^2)	II	III	IV	Total (cm^2)
	Choice				No-choice			
Diamond Express	3.52±0.07	5.63±0.16	5.82±0.17	14.97f	4.13±0.10	5.49±0.16	6.32±0.18	15.94e
Hybrid-1080	3.07±0.05	4.93±0.13	5.11±0.14	13.11e	3.72±0.08	4.89±0.13	4.40±0.11	13.01d
F1-Deepti	1.75±0.02	2.55±0.03	2.90±0.04	7.20c	2.35±0.03	3.14±0.05	3.58±0.07	9.04b
Field Man	1.25±0.01	2.12±0.02	2.66±0.03	6.03b	2.13±0.02	3.28±0.05	3.42±0.06	8.83b
Cabbage-NS-25	3.24±0.05	4.37±0.10	5.63±0.17	13.24e	3.55±0.06	3.65±0.07	4.33±0.10	11.53c
Golden Acre	2.91±0.05	3.75±0.08	4.19±0.10	10.85d	3.29±0.06	4.02±0.09	3.95±0.09	11.26c
Pusa Bold	0.95±0.01	1.18±0.07	1.45±0.01	3.58a	1.41±0.01	1.59±0.01	2.27±0.03	5.27a
Varuna	0.79±0.01	1.20±0.08	1.32±0.01	3.31a	1.15±0.01	1.33±0.01	2.74±0.04	5.22a
Pusa Bahar	0.70±0.01	1.02±0.01	1.25±0.01	2.97a	0.97±0.01	1.22±0.01	2.20±0.02	4.39a
P=0.05				0.69				1.03

Similar alphabets are non significant at 0.05 level

* Mean of five replicates

** Mean of ten replicates

Table-2.4: Larval survival of *P. xylostella* on *Brassica* hosts under protected field condition 2007-08

Stages	Pusa Bold			Varuna			Pusa Bahar			Field Man			Golden Acre			Diamond Express		
x	No.	Dead	Survive	No.	Dead	Survive	No.	Dead	Survive	No.	Dead	Survive	No.	Dead	Survive	No.	Dead	Survive
Choice Test																		
Egg	100.00	13.23	86.77	100.00	12.33	87.67	100.00	10.23	89.77	100.00	9.72	90.28	100.00	5.00	95.00	100.00	4.92	95.08
I instar	86.77	9.66	77.11	87.67	11.00	76.67	89.77	11.45	78.32	90.28	11.23	79.05	95.00	5.60	89.40	95.08	5.29	89.79
II instar	77.11	18.66	58.45	76.67	18.00	58.67	78.32	17.25	61.07	79.05	15.85	63.2	89.40	2.30	87.10	89.79	2.09	87.70
III instar	58.45	14.22	44.23	58.67	16.00	42.67	61.07	16.66	44.41	63.2	12.77	50.43	87.10	3.60	83.50	87.70	3.17	84.53
IV instar	44.23	9.00	35.23	42.67	8.00	34.67	44.41	13.57	30.84	50.43	10.06	40.37	83.50	4.20	79.30	84.53	3.95	80.58
No- Choice Test																		
Egg	100.00	13.45	86.55	100.00	14.26	85.74	100.00	15.00	85.00	100.00	11.59	88.41	100.00	7.66	92.34	100.00	4.52	95.48
I instar	86.55	9.56	76.99	85.74	10.23	75.51	85.00	11.23	73.77	88.41	10.89	73.52	92.34	5.60	86.74	95.48	5.11	90.37
II instar	76.99	8.23	68.76	75.51	6.60	68.91	73.77	10.45	63.32	73.52	9.56	63.96	86.74	4.23	82.51	90.37	3.46	86.91
III instar	68.76	7.26	61.50	68.91	5.89	63.02	63.32	8.56	54.76	63.96	8.25	55.71	82.51	3.20	79.31	86.91	2.62	84.29
IV instar	61.50	5.26	56.24	63.02	7.60	55.42	54.76	7.00	47.76	55.71	5.47	50.24	79.31	3.12	76.19	84.29	1.53	82.76

Table-2.5: Larval survival of *P. xylostella* on *Brassica* hosts under protected field condition 2008-09

Stages	Pusa Bold			Varuna			Pusa Bahar			Field Man			Golden Acre			Diamond Express		
x	No.	Dead	Survive	No.	Dead	Survive	No.	Dead	Survive	No.	Dead	Survive	No.	Dead	Survive	No.	Dead	Survive
Choice Test																		
Egg	100.00	12.33	87.67	100.00	11.66	88.34	100.00	9.66	90.34	100.00	8.74	91.26	100.00	5.46	94.54	100.00	4.27	95.73
I instar	87.67	8.56	79.11	88.34	10.22	78.12	90.34	10.45	79.89	91.26	9.05	82.21	94.54	5.23	89.31	95.73	4.11	91.62
II instar	79.11	15.66	63.45	78.12	17.88	60.24	79.89	16.56	63.33	82.21	15.85	66.36	89.31	3.32	85.99	91.62	3.39	88.23
III instar	63.45	13.22	50.23	60.24	15.23	45.01	63.33	15.71	47.62	66.36	14.77	51.59	85.99	3.55	82.44	88.23	2.73	85.50
IV instar	50.23	8.55	41.68	45.01	6.11	38.90	47.62	14.23	33.39	51.59	12.06	39.53	82.44	3.21	79.23	85.50	2.38	83.12
No-choice Test																		
Egg	100.00	14.25	85.75	100.00	15.36	84.64	100.00	11.00	89.00	100.00	11.59	88.41	100.00	6.67	93.33	100.00	5.27	94.73
I instar	85.75	11.55	74.20	84.64	11.73	72.91	89.00	11.53	77.47	88.41	10.89	77.52	93.33	5.39	87.94	94.73	4.63	90.10
II instar	74.20	7.98	66.22	72.91	8.84	64.07	77.47	12.65	64.82	77.52	9.56	67.96	87.94	3.15	84.79	90.10	2.87	87.23
III instar	66.22	7.32	58.90	64.07	7.97	56.10	64.82	9.56	55.26	67.96	8.34	59.62	84.79	3.40	81.39	87.23	3.27	83.96
IV instar	58.90	5.43	53.47	56.10	5.38	50.72	55.26	6.00	49.26	59.62	5.47	54.15	81.39	3.12	78.27	83.96	2.90	81.06

Table-2.6: Larval survival of *P. xylostella* on *Brassica* hosts at constant temperatures

Stages	Pusa Bold			Varuna			Pusa Bahar			Field Man			Golden Acre			Diamond Express		
x	No.	Dead	Survive	No.	Dead	Survive	No.	Dead	Survive	No.	Dead	Survive	No.	Dead	Survive	No.	Dead	Survive
10°C																		
Egg	100.00	20.80	79.20	100.00	23.10	76.90	100.00	22.20	77.80	100.00	30.45	69.55	100.00	16.28	83.72	100.00	9.63	90.37
I instar	79.20	16.10	63.10	76.90	18.20	58.70	77.80	17.35	60.45	69.55	23.20	46.35	83.72	17.18	66.54	90.37	10.06	80.31
II instar	63.10	17.75	45.35	58.70	12.20	46.50	60.45	16.45	44.00	46.35	17.18	29.17	66.54	8.25	58.29	80.31	6.33	73.98
III instar	45.35	16.90	28.45	46.50	17.10	29.40	44.00	18.78	25.22	29.17	12.47	16.70	58.29	5.10	53.19	73.98	4.60	69.38
IV instar	28.45	11.30	17.15	29.40	12.35	17.05	25.22	12.34	12.88	16.70	10.23	6.47	53.19	5.50	47.69	69.38	4.78	64.60
15°C																		
Egg	100.00	17.82	82.18	100.00	17.28	82.72	100.00	18.20	81.80	100.00	20.87	79.13	100.00	11.26	88.74	100.00	10.45	89.55
I instar	82.18	12.20	69.98	82.72	15.21	67.51	81.80	16.33	65.47	79.13	22.61	56.52	88.74	11.35	77.39	89.55	10.70	78.85
II instar	69.98	15.26	54.72	67.51	17.12	50.39	65.47	10.18	55.29	56.52	19.33	37.19	77.39	6.75	70.64	78.85	6.33	72.52
III instar	54.72	16.20	38.52	50.39	13.20	37.19	55.29	14.29	41.00	37.19	14.58	22.61	70.64	5.88	64.76	72.52	5.60	66.92
IV instar	38.52	8.78	29.74	37.19	10.47	26.72	41.00	11.22	29.78	22.61	11.29	11.32	64.76	4.79	59.97	66.92	4.98	61.94
20°C																		
Egg	100.00	14.55	85.45	100.00	16.58	83.42	100.00	17.56	82.44	100.00	17.39	82.61	100.00	10.25	89.75	100.00	8.23	91.77
I instar	85.45	13.25	72.20	83.42	14.65	68.77	82.44	15.26	67.18	82.61	16.55	66.06	89.75	8.24	81.51	91.77	8.87	82.90
II instar	72.20	14.21	57.99	68.77	13.24	55.53	67.18	8.56	58.62	66.06	14.98	51.08	81.51	4.75	76.76	82.90	4.62	78.28
III instar	57.99	15.16	42.83	55.53	16.62	38.91	58.62	10.22	48.40	51.08	14.5	36.58	76.76	5.46	71.30	78.28	5.11	73.17
IV instar	42.83	8.45	34.38	38.91	12.23	26.68	48.40	8.45	39.95	36.58	13.11	23.47	71.30	4.66	66.64	73.17	4.35	68.82
25°C																		
Egg	100.00	16.75	83.25	100.00	15.79	84.21	100.00	16.55	83.45	100.00	13.29	86.71	100.00	10.24	89.76	100.00	8.97	91.03
I instar	83.25	10.46	72.79	84.21	12.65	71.56	83.45	16.48	66.97	86.71	13.45	74.26	89.76	9.85	79.91	91.03	8.72	82.31
II instar	72.79	15.62	57.17	71.56	16.24	55.32	66.97	17.55	49.42	74.26	13.37	60.89	79.91	6.56	73.35	82.31	5.55	76.76
III instar	57.17	12.46	44.71	55.32	10.23	45.09	49.42	9.56	39.86	60.89	12.77	48.12	73.35	5.64	67.71	76.76	5.28	71.48
IV instar	44.71	10.43	34.28	45.09	7.89	37.20	39.86	8.25	31.61	48.12	12.50	35.62	67.71	4.57	63.14	71.48	2.11	69.37
30°C																		
Egg	100.00	18.25	81.75	100.00	17.27	82.73	100.00	18.25	81.75	100.00	18.61	81.39	100.00	12.05	87.95	100.00	9.63	90.37
I instar	81.75	12.23	69.52	82.73	16.46	66.27	81.75	17.23	64.52	81.39	15.06	66.33	87.95	11.86	76.09	90.37	10.26	80.11
II instar	69.52	17.32	52.20	66.27	15.55	50.72	64.52	16.32	48.20	66.33	14.45	51.88	76.09	8.69	67.40	80.11	6.45	73.66
III instar	52.20	13.09	39.11	50.72	13.06	37.66	48.20	14.09	34.11	51.88	13.63	38.25	67.40	7.23	60.17	73.66	6.39	67.27
IV instar	39.11	11.86	27.25	37.66	11.46	26.20	34.11	11.86	22.25	38.25	12.90	25.35	60.17	6.89	53.28	67.27	5.53	61.74

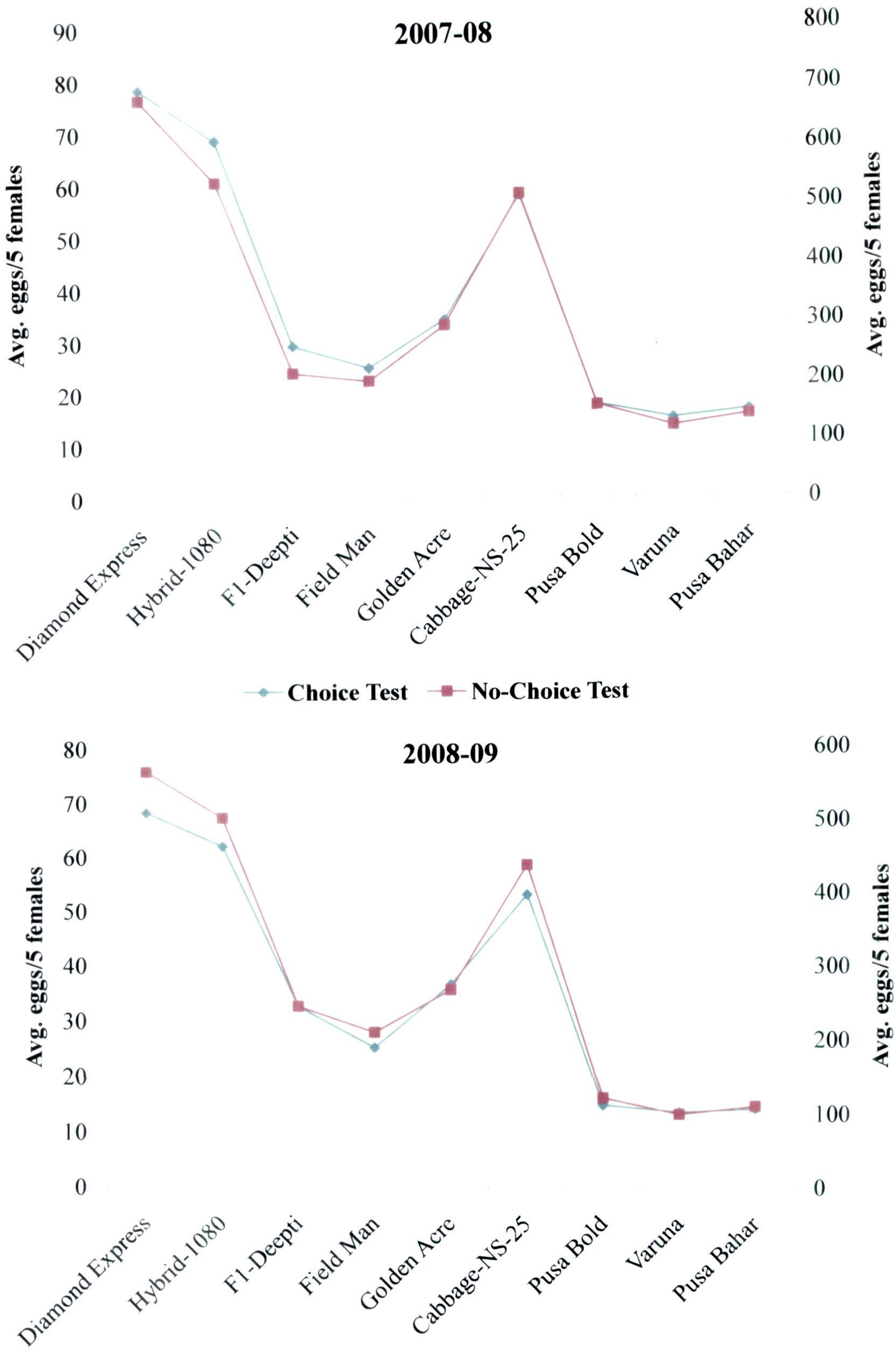
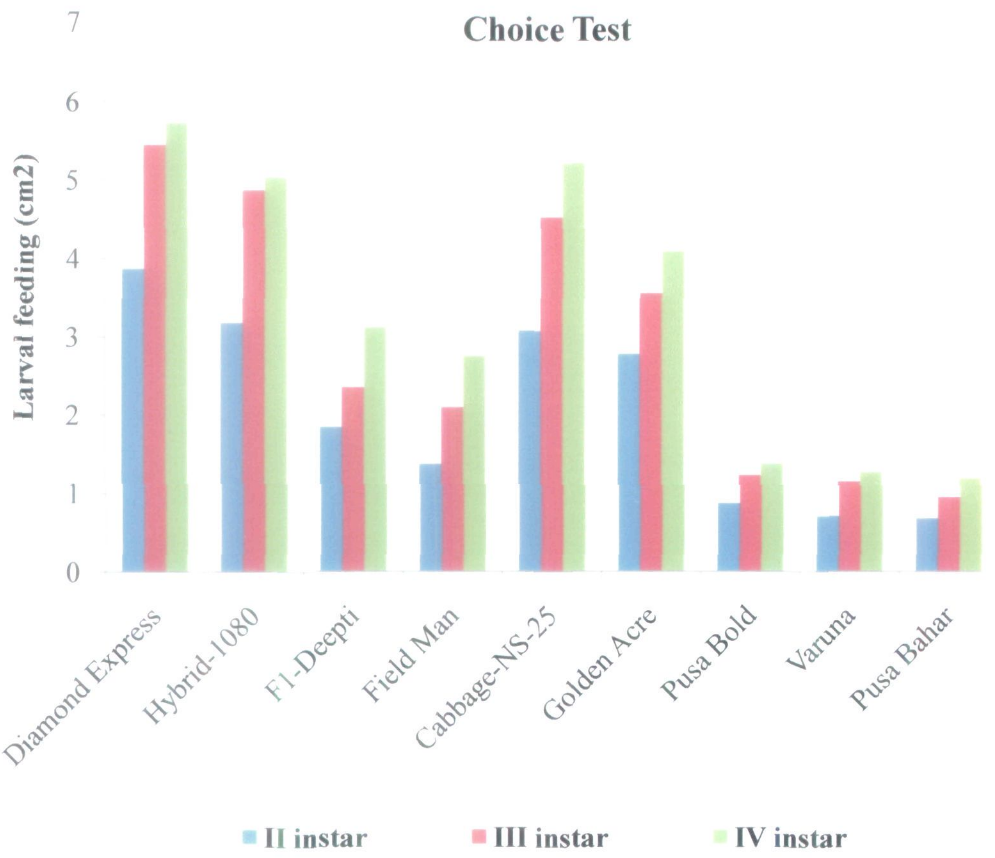


Fig-2.1: Oviposition of *P. xylostella* on *Brassica* hosts



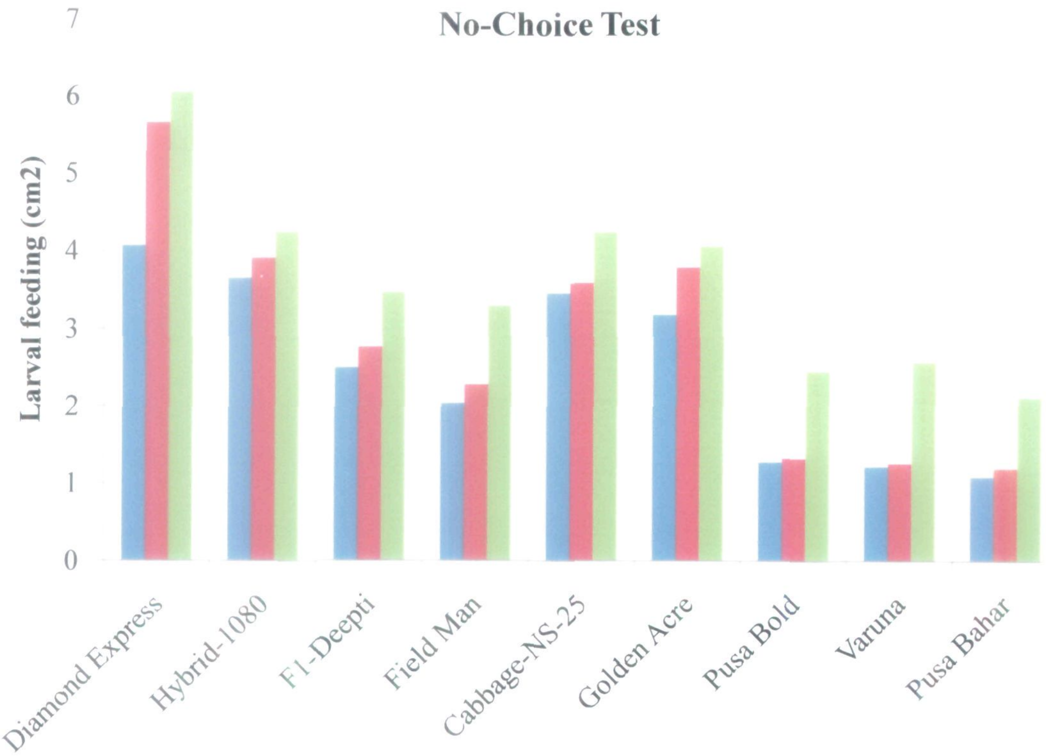


Fig-2.2: Larval feeding of *P. xylostella* on *Brassica* hosts (2007-08)

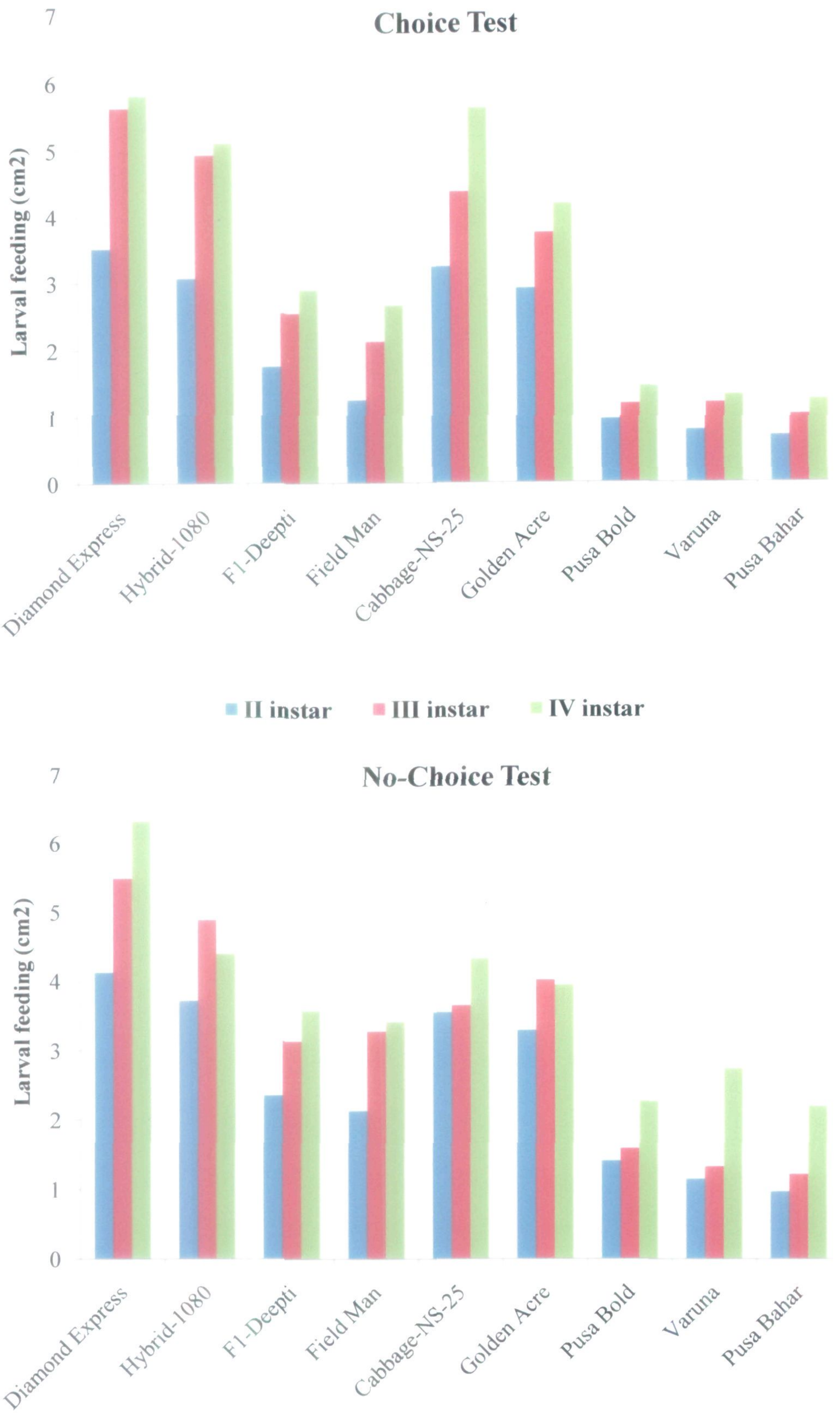


Fig-2.3: Larval feeding of *P. xylostella* on *Brassica* hosts (2008-09)

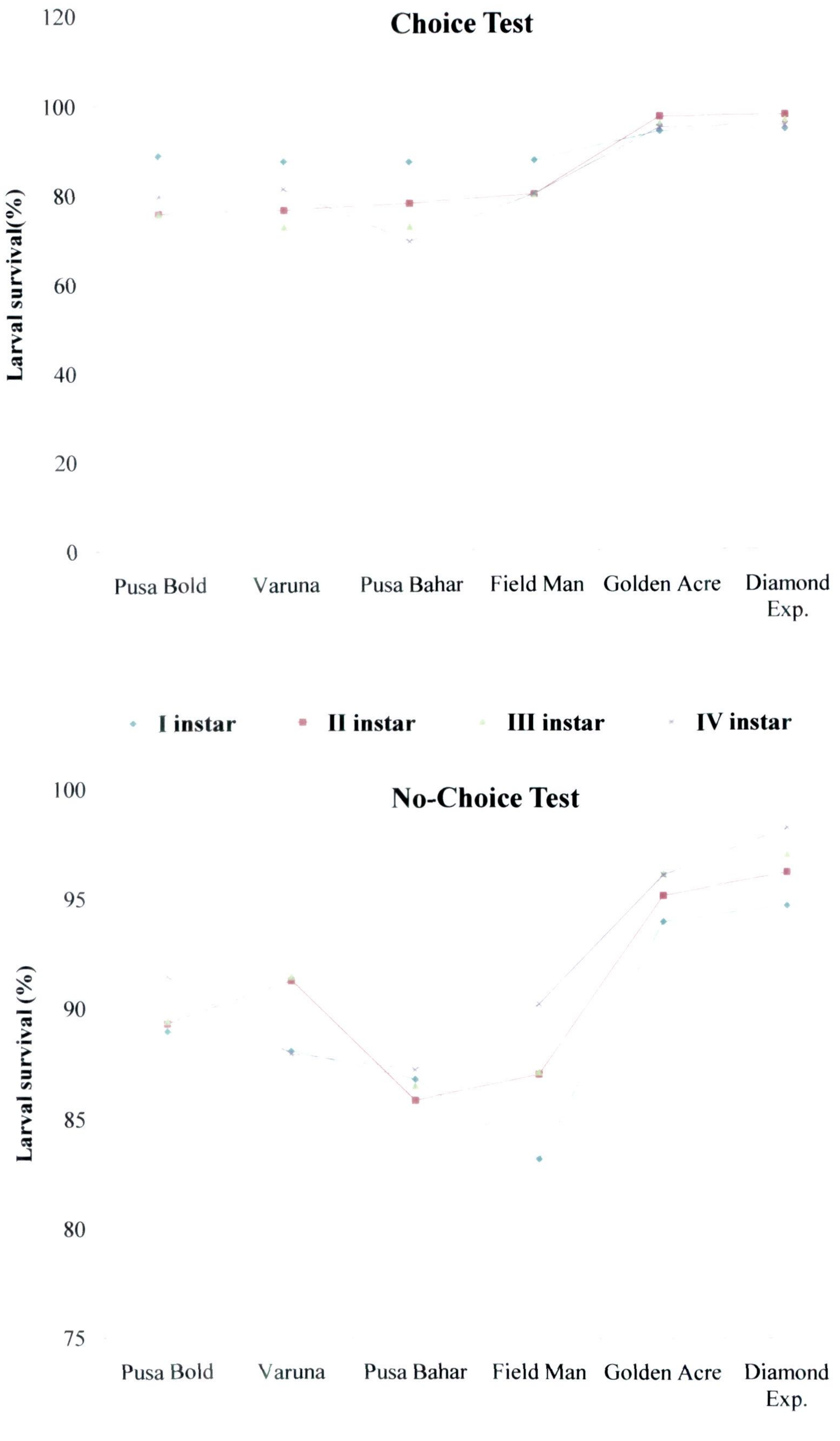


Fig-2.4: Larval survival of *P. xylostella* on *Brassica* hosts (2007-08)

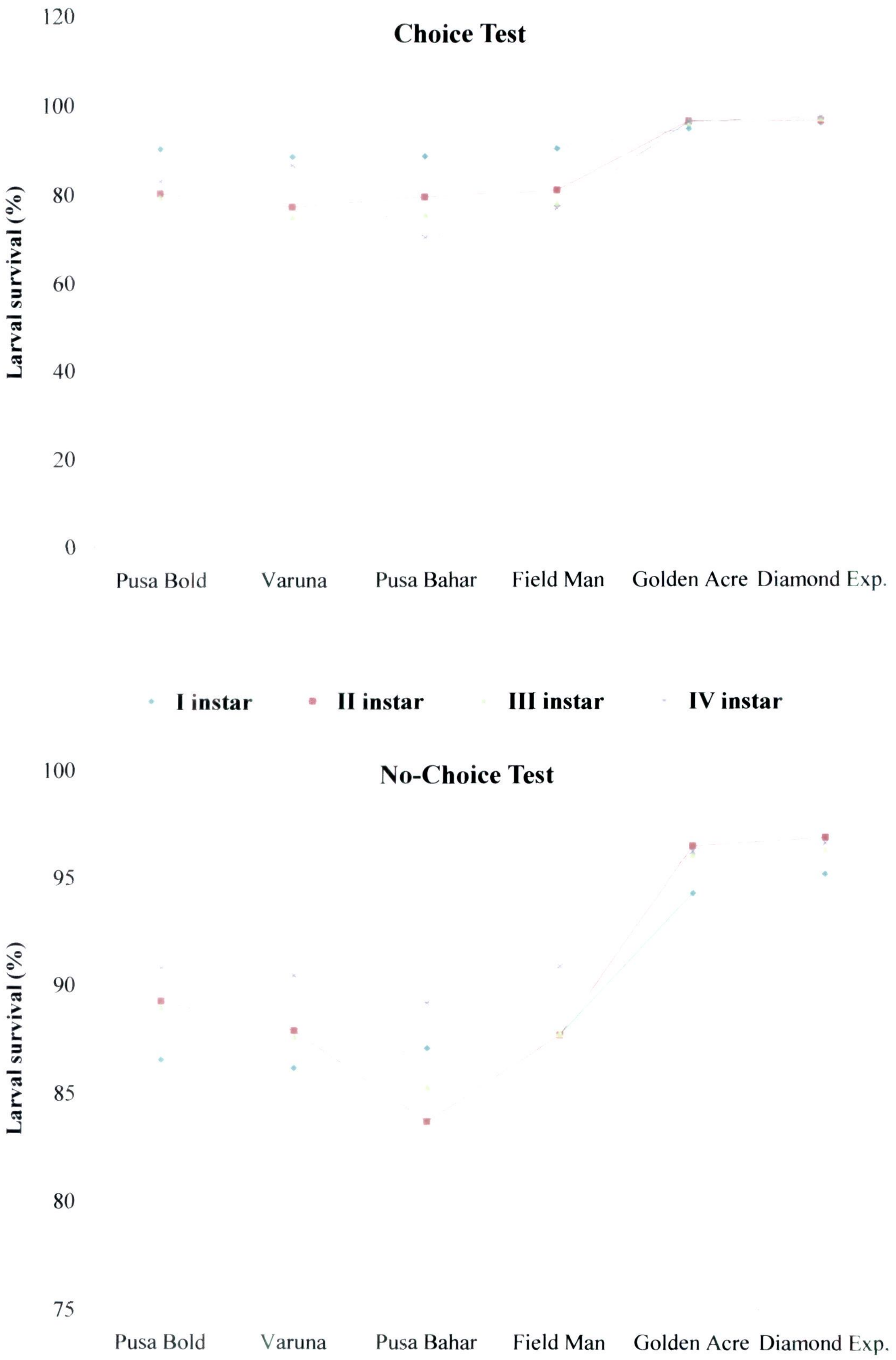


Fig-2.5: Larval survival of *P. xylostella* on *Brassica* hosts (2008-09)

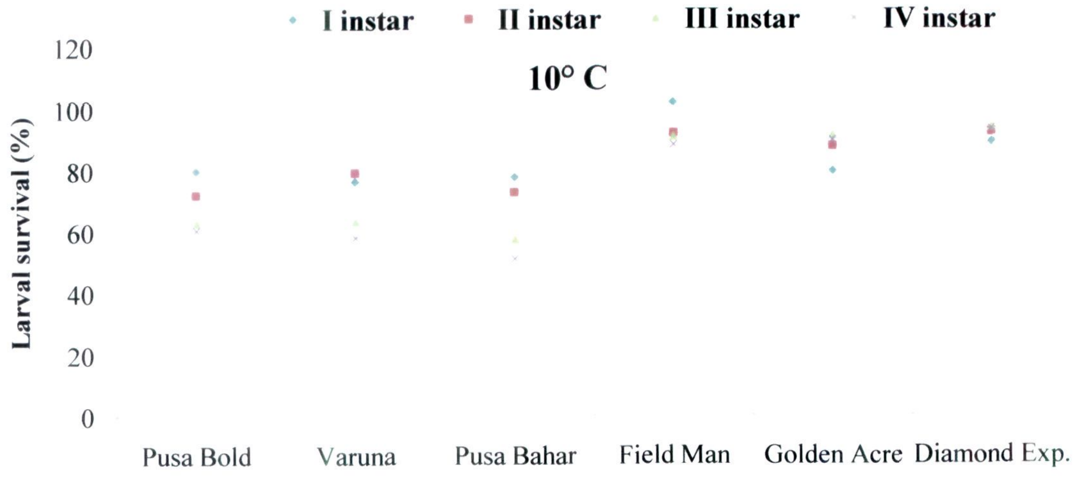


Fig-2.6: Larval survival of *P. xylostella* on *Brassica* hosts at 10°C

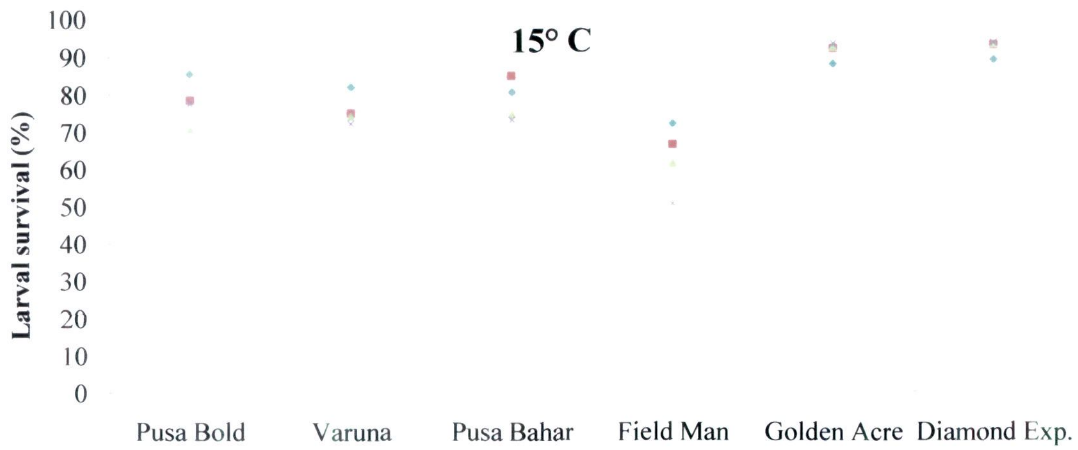


Fig-2.7: Larval survival of *P. xylostella* on *Brassica* hosts at 15°C

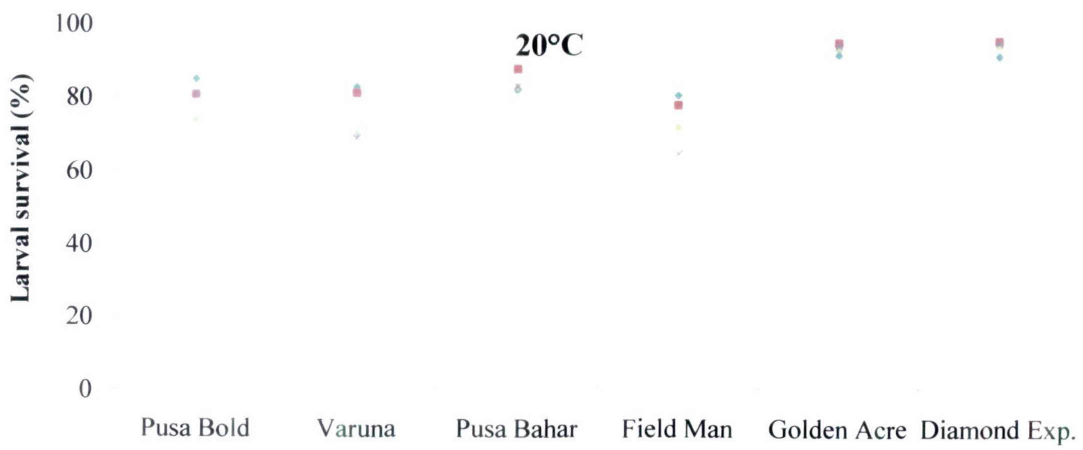


Fig-2.8: Larval survival of *P. xylostella* on *Brassica* hosts at 20°C

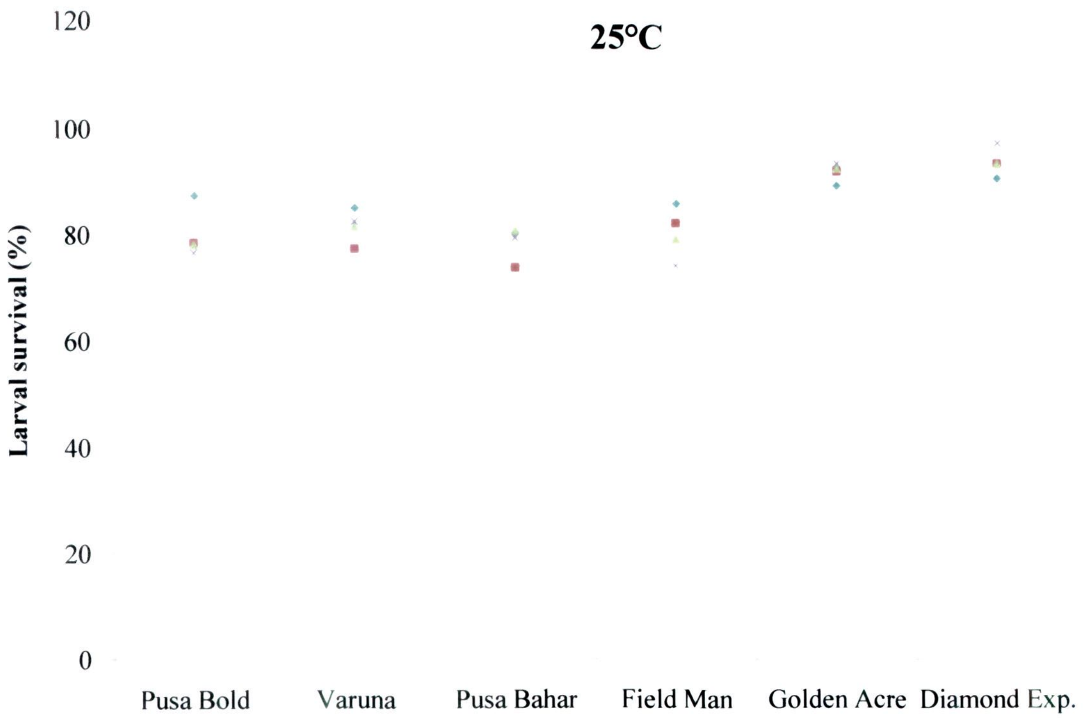


Fig-2.9: Larval survival of *P. xylostella* on *Brassica* hosts at 25°C

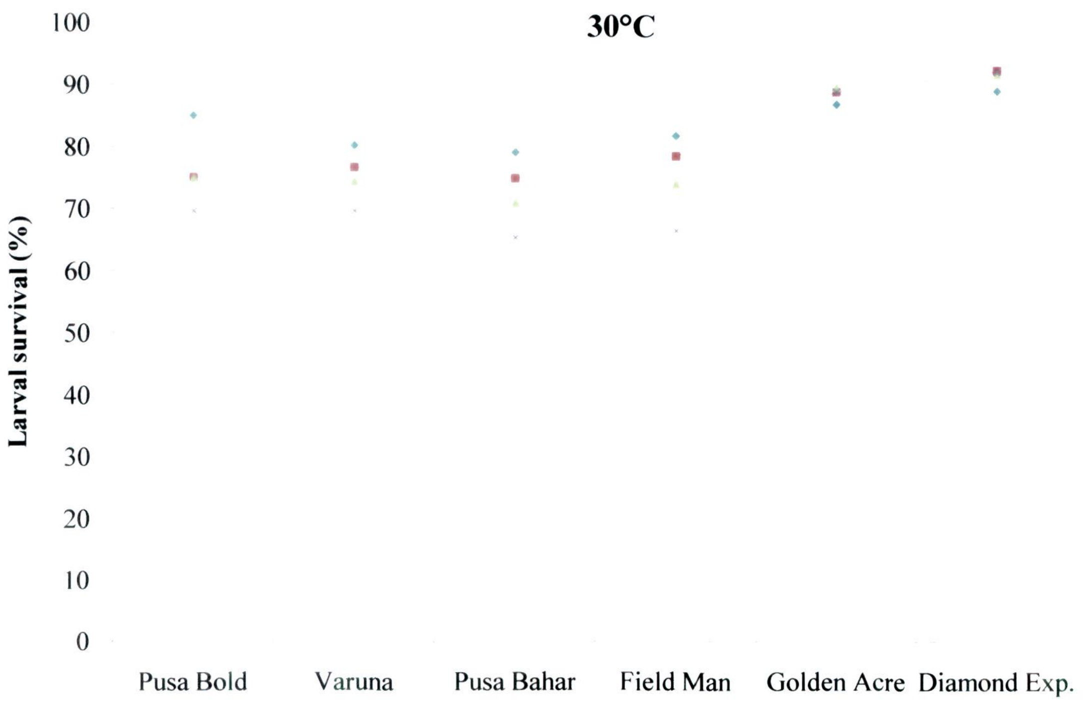


Fig-2.10: Larval survival of *P. xylostella* on *Brassica* hosts at 30°C

3. Studies on the life table of *P. xylostella* on *Brassica* hosts:

a. Age specific life table:

Table (3.1, 3.2, 3.3, 3.4, 3.5, 3.6) showed that survival of *P. xylostella* decreases with advancing age and also depends on the host plants. Survivorship was greater on cabbage varieties than on Indian mustard (Fig. 3.1). Highest number of eggs were hatched on cabbage i.e. Diamond Express followed by Golden Acre and Field Man as compared to Indian mustard. Mortality of egg was highest when *P. xylostella* reared on Pusa Bahar and lowest on Diamond Express. Mortality also occurred at different stages of *P. xylostella* and larval mortality was more on Indian mustard than cabbage varieties and least on Diamond Express (Fig. 3.2). The duration of immature stages from egg to pupa was 25 days on Indian mustard and prolonged to 27 days on Diamond Express. Adult emergence was highest on cabbage i.e. Diamond Express followed by Golden Acre, Field Man as compared to Indian mustard. Expectancy was greatest in the beginning of age then decreases with increasing age. The greatest expectancy of life was recorded on cabbage i.e. Diamond Express followed by Golden Acre and Field Man as compared to Indian mustard varieties i.e. on Varuna followed by Pusa Bahar and Pusa Bold (Fig. 3.3).

b. Fecundity and life indices: (Table 3.7. 3.8, 3.9, 3.10, 3.11, 3.12, 3.13):

Pre-oviposition period lasted for one day in all the host plants (Table 3.7 to 3.12). Host plants significantly ($P<0.05$) affect the fecundity of *P. xylostella*. Highest number of eggs laid by a female of *P. xylostella* 24 hr after emergence and slowly decreases with advancing of age. *P. xylostella* preferred to lay more eggs on cabbage varieties i.e. Diamond Express than other varieties of cabbage and Indian mustard. Total oviposition period was 8-days on Indian mustard while, 9, 10 and 11 days on Field Man, Golden Acre and Diamond Express, respectively. Female birth rate (m_x) was highest when *P. xylostella* fed on Diamond Express while, lowest on Pusa Bahar (Table 3.7 to 3.12).

Potential fecundity (*Pf*): Results of life table indices (Table-3.13) showed that highest potential fecundity (*Pf*) occurred on Diamond Express i.e. 124.05 and lowest on Pusa Bahar i.e. 52.42 females/female/generation followed by on Golden Acre (90.56), Field Man (75.20), Pusa Bold (63.57) and Varuna (55.87).

Net reproductive rate (R_0): R_0 is significantly ($P<0.05$) differed on Field Man, Golden Acre, Diamond Express and Pusa Bold and not significantly differed on Varuna and Pusa

Bahar. 7.78 females/female/generation were obtained on Varuna and highest i.e. 64.99 on Diamond Express (Table 3.13 and Fig. 3.4).

Intrinsic rate of increase (r_m): Table 3.13 showed that r_m is significantly/not significantly differed on *Brassica* hosts. Highest r_m occurred on Golden Acre (0.049) and lowest i.e. 0.027 females/female/day on Varuna followed by Diamond Express and Pusa Bold. r_m is significantly (P<0.05) reduced when *P. xylostella* reared on Indian Mustard.

Finite rate of increase (λ): Lowest finite rate of increase (λ) i.e. 1.027 females/female/day was found on Varuna and highest on Golden Acre i.e. 1.050.

Mean generation time (T_c): *P. xylostella* when reared on Pusa Bahar is required 26.95 days to complete one generation and prolonged to 29.57 days on Diamond Express. While, fractional difference was recorded on Pusa Bold, Varuna, Field Man and Golden Acre.

Corrected generation time (τ): 38.01 days were required by *P. xylostella* to complete one generation on Diamond Express followed by Golden Acre and Field Man. While, almost equal days required by *P. xylostella* to complete one generation on Pusa Bold and Varuna.While, the least i.e. 34.04 days occurred on Field Man (Table-3.13).

Doubling time (*DT*): Population of *P. xylostella* will become double in 6.94 days on Pusa Bold while extended to 10.45 days on Pusa Bahar and 11.15 days on Varuna. *P. xylostella* multiplies fast on cabbage varieties as compared to Indian mustard.

Life table parameters are significantly (P<0.05) influenced by host plants. Survival and mortality of *P. xylostella* is affected by host plants when reared on them. Justin *et al.* (2001) obtained average duration of immature stages of DBM as 21, 22 and 25 days on cauliflower, cabbage and Indian mustard, respectively. In the present study the duration of immature stages was 25 days on Indian mustard and 27 days on Diamond Express of cabbage. Sundaram and Dhandapani (2008) reported the average duration of immature stages on untreated and treated cauliflower leaves as 19 and 20 days, respectively and preoviposition period lasted for 3 days on both tests. Mortality of immature stages of *P. xylostella* is less on cauliflower and high on radish (Ahmad, 2008) and the same result is also obtained by Syed and Abro (2003) on the larval mortality of *P. xylostella.* Dabhi *et al.* (2009) reported that preoviposition period was between 22nd and 24th days of pivotal age. While, the average duration of immature stages recorded 22 days. In the present study the maximum longevity of the reproductive female recorded 8 days in all Indian mustard varieties. While, it was 9, 10 and 11 days on Field Man, Golden Acre and Diamond Express, respectively. Longevity of *P. xylostella* is prolonged to 14 days on cauliflower and cabbage followed by Indian mustard, broccoli and shortened to 6 days on radish (Ahmad, 2008) and longevity varies between the seasons. Development period of immature stage of *P. xylostella* was shortest and prolonged on cauliflower and radish, respectively (Ahmad, 2008). However, Hamilton *et al.* (2005) reported the development time of *P. xylostella* that the larvae developed more rapidly on Green coronet cabbage than Savoy king. Similar result reported by Koshihara (1986) as 7-9 days at 22.5°C. Wakisaka (1992) reported that longevity of adult showed great variability from location to location.

Maximum eggs are laid on *Brassica napus* as compared to *B. juncea*, which is less preferred because the leaves of *B. juncea* are hairy/spiny (Ahmad *et al.* 2008). Leaves of *B. napus* were more preferred for oviposition because of hairy and glossy leaf surface which has reduced wax load (Andrehennadi and Gillott, 1998, Eigenbrode and Shelton, 1992) that improves the adhesiveness of eggs (Uematsu and Sakanoshita, 1989). Ulmar *et al.* (2002) have also reported that more eggs were laid on glossy varieties of *B. rapa* plants than on waxy plants. In the present study, *P. xylostella* laid more eggs on cabbage varieties as compared to Indian mustard. It was also reported by Syed and Abro (2003) that highest numbers of eggs were laid by *P. xylostella* when larvae reared on cauliflower followed by cabbage in comparison to turnip and radish. Although, fecundity seems to be dependent on quality of food (Koshihara, 1986) and generally, insect oogenesis has been shown to increase with host quality (Hopkins and Ekbom, 1999, Papaj, 2000). Significantly greater number of eggs laid by *P. xylostella* on cabbage than on cauliflower, broccoli and kohlrabi (Reddy *et al.*, 2004). DBM laid significantly higher number of eggs on wild crucifers than on cabbage and kale but highest number of eggs was on *Rorippa micrantha* and the least on cabbage in both choice and no-choice tests (Kahuthia-Gathu *et al.* 2008). Moreover, Badenes-Perez *et al.* (2004) recorded 12 times higher oviposition on yellow rocket, *B. vulgaris* than on cabbage, yet yellow rocket does not support larval development and has even been termed as dead end trap crop (Lu *et al.*, 2000, Shelton and Nault, 2004). Further studies of Badenes–Perez *et al.* (2006) showed that *P. xylostella* laid 28 percent more eggs on *B. vulgaris* var. *arcuata* than on cabbage. Since the number and placement of eggs is the result of a whole sequence of behavioural steps that start with long range attraction mediated by semiochemicals (Bernays and Chapman, 1994, Hardie *et al.*, 2001) and green leaf volatiles (Reddy and Guerrero, 2000) and non volatile glucosinolate (Renwick and Radke, 1990). Charleston and Kfir (2000) revealed that *P. xylostella* preferred to lay highest number of eggs on Indian mustard as compared to cabbage, cauliflower and broccoli. Dabhi *et al.* (2009) reported that the females contributed the highest number of progeny (*mx*= 22.21) on 27th day of pivotal age, which decreased day by day. In the present study the highest number of progeny (m_x= 26.84) on 27th day of pivotal age found on Diamond Express, which decreased gradually day by day. Expectancy of life of *P. xylostella* was declined gradually with the advancement of age on all the *Brassica* varieties (Table 3.1-3.6). This finding is in the conformity with Hemchandra and Singh (2005), where they stated that life expectancy of newly deposited eggs was 7.59 days while it was 5.47 days at the time of adult emergence and only 1 day on the cessation of life cycle. Although, a female DBM may lays 233 eggs in 12 days (Poelking, 1992), 230 eggs (Ho, 1965), 243 eggs (Bhalla and Dubey, 1986). It was suggested by Chen and Su (1986) that a high variation exist in fecundity ranging from zero to several hundred eggs/female and this could be result either of inclusion of data taken from unmated females or because the number of eggs laid is directly related to the longevity of female which is also quite, while, Harcourt (1957) found 18-356 eggs/female of *P. xylostella* with an average of 159 eggs/female. But Enkegaard (1993) and Yang *et al.* (1994) suggested that number of offspring produced increases with temperature but high temperature reduced fecundity, which is almost in conformity with the results under present studies where highest number of eggs i.e. 252.40 was collected from Diamond Express within 11 days and the lowest from Pusa Bahar i.e. 103.84 eggs in a period of 8 days. Ahmad (2008) has collected 241.26 eggs/female on cauliflower, 196.24 eggs on cabbage, 137 eggs on *B. juncea* var. Pusa Bold, and 117 eggs on *B. campestris* var. BSH-1 and also observed the variation in the number of eggs in two cropping seasons.

In the present study, R_o is significantly ($P<0.05$) differed on cabbage and Indian mustard varieties. R_o of cabbage varieties was higher as compared to Indian mustard. The net reproductive rate (R_o) 95.33 was obtained by Dabhi *et al.* (2009) with a mean length of generation (T) of 27.87 days. Sundaram and Dhandapani (2008) mentioned the value of net reproductive rate (R_o) as 69.54 and 61.05 on untreated and treated cauliflower leaves indicating that the population of *P. xylostella* was able to multiply 69.54 and 61.05 times on the untreated and treated leaves in the corrected generation time of 23.37 and 25.69 days, respectively. Auad and Moraes (2003) reported that R_o of *P. xylostella* was highest at 20°C and lowest at 25°C. While, Shirai (2000) found a higher net reproductive rate between 29° and 31°C as larval developmental periods are extremely short at such high temperature, although egg production by females decreases with temperature increases. R_o tends to increase from 10° to 20° C then declines gradually up to 35° C (Ahmad, 2008) and also affected by host plants. R_o of *P. xylostella* was highest on cauliflower followed by *B. juncea* (12.99) and smallest on radish (4.32). Syed and Abro (2003) reported that broccoli yielded a greater R_o (197.03 female/female) followed by cabbage and smallest on *C. bursa-pastoris* (Wakisaka *et al.*, 1992) while, Kahuthia-Gathu *et al.* (2008) obtained highest R_o on wild crucifer, *R. micrantha* as compared to cabbage and kale. Golizadeh *et al.* (2009) detected the highest and lowest net reproductive rate on cabbage cultivars in the laboratory at 25±1°C, 65±5 %RH and 14L: 10D hours photoperiodism which further confirms the findings of the present studies where life table of *P. xylostella* was studied at 22±1°C and 70±5% relative humidity.

The intrinsic rate of increase (r_m) is the only static that adequately summarizes the physiological qualities of an animal relative to its capacity of increase (Andrewartha and Birch, 1954), and provides an effective summary of an insects life history traits (Dixon, 1987) as well as a good indicator of the temperature at which growth of a population is most favourable because it reflects over all the effect of temperature on development, reproduction and survival characteristic of a population (Wang *et al.*, 1997) and often used by ecologist and pest management scientists as a comparative statistics for revealing the impact of parameter (e.g. temperature, host plants) on insect demographic potentials (Hance *et al.*, 1994). In the present study, r_m is significantly/nonsignificantly differed on host plants. Greater r_m occurred on cabbage varieties than Indian mustard. Ahmad (2008) found greatest r_m at 25°C i.e. 0.1956 females/female/day and smallest at 10°C i.e. 0.0284 whereas, r_m is nearly equal at 20° and 35°C on *P. xylostella.* He also obtained greatest r_m on cauliflower (0.1413) followed by cabbage (0.1175) and smallest on radish (0.004) while working on mustard, he reported that r_m was 0.0992 and 0.0537 females/female/day on *B. napus* Var. Neelam and *B. campestris* var. BSH-1 , respectively and slightly higher r_m (0.0619) recorded on *B. juncea* var. Pusa Bold. He also reported variation in r_m of *P. xylostella* on *Brassica* host plants between the two cropping seasons. Syed and Abro (2003) found highest r_m on broccoli as compared to cauliflower, cabbage and greater r_m was recorded on *R. micrantha* than cabbage and kale (Kahuthia-Gathu *et al.* 2008). Golizadeh *et al.* (2007) reported that r_m was highest at 25°C i.e. 0.285 females/females/day. They further reported in 2009 that the highest r_m was found on cauliflower and cabbage, respectively and lowest on canola which is also closely followed by the findings under present studies.

Finite rate of increase (λ) is significantly/ non significantly affected by host plants. Fractional difference was found on cabbage and Indian mustard varieties. Ahmad (2008) reported that finite rate of increase (λ) varies with temperature and host plants and highest multiplying rate in unit time of *P. xylostella* is 1.216 females/female/day at 25°C and lowest at 10°C followed by cabbage (1.12), radish (1.14), Indian mustard (1.06), *B. napus* var. *neelam* (1.1), *B. campestris* var. *BSH-1* (1.06) and found variation in two cropping seasons. Hemchandra and Singh (2003) reported finite rate of increase was 1.13 females/female/day on cauliflower and further in 2005, they recorded it as 1.117 females/female/day on *B. juncea*. They recorded a comparatively greater finite rate of increase (λ) on cauliflower than Indian mustard varieties. Under present findings greater finite rate of increase (λ) has been mentioned on cabbage varieties than Indian mustard.

In the present studies, generation time was longer (29.56 days) when *P. xylostella* fed on Diamond Express of cabbage and shortest on *B. juncea* var. Pusa Bahar. Justin *et al.* (2001) reported corrected generation time as 22.26, 23.66 and 17.5 days on cauliflower, cabbage and Indian mustard, respectively. Shorter T_c was on cauliflower and prolonged on *Rophamus sativus* (Syed and Abro, 2003) but shorter generation time was found on broccoli and prolonged on cabbage (Wakisaka *et al.,* 1992).A significantly long generation time of *P. xylostella* (93.44 days) was at 10°C and shortest i.e. 15.93 days at 33 °C (Ahmad, 2008). He also reported that 29.73 days required by *P. xylostella* to complete a single generation on cauliflower under field condition and prolonged to 35.11 days on radish. *P. xylostella* required 39.65 and 39.76 days to complete one generation on *B. campestris* var. *BSH-1* and *B. juncea* var. Pusa Bold, respectively. Golizadeh *et al.* (2009) reported longest mean generation time on cabbage cultivars. While Kahuthia-Gathu *et al.* (2008) reported longest generation time i.e. 31.7 days on *R. micrantha* and prolonged on cabbage. While, Sundaram and Dhandapani (2008) mentioned it as 23.37 and 25.69 days on untreated and treated cauliflower, respectively.

In present study, *P. xylostella* multiplies fast on cabbage and 11.14 days on Varuna. Ahmad (2008) found shortest (3.54 days) doubling time at 25 °C and prolonged to 24.41 days at 10 °C. He also reported that population of *P. xylostella* will become double in 4.91 days on cauliflower, 5.9 days on cabbage and prolonged to 19.28 days on radish. Further, studies of Ahmad (2008) showed that doubling time of *P. xylostella* was 6.99 days when reared on *B. napus* var. Neelam and 11.20 days on *B. juncea* var. Pusa Bold. Sundaram and Dhandapani (2008) described the doubling time of *P. xylostella* as 3.01 and 3.34 days on untreated and treated cauliflower, respectively.

Table-3.1: Age specific life table of *P. xylostella* on Pusa Bold

x	lx	dx	$100qx$	Lx	Tx	ex
0	100	0	0.000	100.0	2058.0	20.580
1	100	0	0.000	100.0	1958.0	19.580
2	100	0	0.000	100.0	1858.0	18.580
3	100	9	9.000	95.5	1758.0	18.408
4	91	2	2.198	90.0	1662.5	18.472
5	89	3	3.371	87.5	1572.5	17.971
6	86	2	2.326	85.0	1485.0	17.471
7	84	4	4.762	82.0	1400.0	17.073
8	80	2	2.500	79.0	1318.0	16.684
9	78	3	3.846	76.5	1239.0	16.196
10	75	1	1.333	74.5	1162.5	15.604
11	74	3	4.054	72.5	1088.0	15.007
12	71	2	2.817	70.0	1015.5	14.507
13	69	3	4.348	67.5	945.5	14.007
14	66	2	3.030	65.0	878.0	13.508
15	64	1	1.563	63.5	813.0	12.803
16	63	3	4.762	61.5	749.5	12.187
17	60	3	5.000	58.5	688.0	11.761
18	57	2	3.509	56.0	629.5	11.241
19	55	5	9.091	52.5	573.5	10.924
20	50	0	0.000	50.0	521.0	10.420
21	50	0	0.000	50.0	471.0	9.420
22	50	0	0.000	50.0	421.0	8.420
23	50	0	0.000	50.0	371.0	7.420
24	50	4	8.000	48.0	321.0	6.688
25	46	0	0.000	46.0	273.0	5.935
26	46	0	0.000	46.0	227.0	4.935
27	46	0	0.000	46.0	181.0	3.935
28	46	0	0.000	46.0	135.0	2.935
29	46	13	28.261	39.5	89.0	2.253
30	33	12	36.364	27.0	49.5	1.833
31	21	9	42.857	16.5	22.5	1.364
32	12	12	100.000	6.0	6.0	1.000

Table-3.2: Age specific life table of *P. xylostella* on Varuna

x	*lx*	*dx*	*100qx*	*Lx*	*Tx*	*ex*
0	100	0	0.000	100.0	1439.0	14.390
1	100	0	0.000	100.0	1339.0	13.390
2	100	0	0.000	100.0	1239.0	12.390
3	100	16	16.000	92.0	1139.0	12.380
4	84	4	4.762	82.0	1047.0	12.768
5	80	3	3.750	78.5	965.0	12.293
6	77	5	6.494	74.5	886.5	11.899
7	72	2	2.778	71.0	812.0	11.437
8	70	3	4.286	68.5	741.0	10.818
9	67	4	5.970	65.0	672.5	10.346
10	63	5	7.937	60.5	607.5	10.041
11	58	3	5.172	56.5	547.0	9.681
12	55	5	9.091	52.5	490.5	9.343
13	50	3	6.000	48.5	438.0	9.031
14	47	6	12.766	44.0	389.5	8.852
15	41	7	17.073	37.5	345.5	9.213
16	34	3	8.824	32.5	308.0	9.477
17	31	3	9.677	29.5	275.5	9.339
18	28	2	7.143	27.0	246.0	9.111
19	26	4	15.385	24.0	219.0	9.125
20	22	0	0.000	22.0	195.0	8.864
21	22	0	0.000	22.0	173.0	7.864
22	22	0	0.000	22.0	151.0	6.864
23	22	0	0.000	22.0	129.0	5.864
24	22	6	27.273	19.0	107.0	5.632
25	16	0	0.000	16.0	88.0	5.500
26	16	0	0.000	16.0	72.0	4.500
27	16	0	0.000	16.0	56.0	3.500
28	16	4	25.000	14.0	40.0	2.857
29	12	3	25.000	10.5	26.0	2.476
30	9	2	22.222	8.0	15.5	1.938
31	7	3	42.857	5.5	7.5	1.364
32	4	4	100.000	2.0	2.0	1.000

Table-3.3: Age specific life table of *P. xylostella* on Pusa Bahar

x	lx	dx	$100qx$	Lx	Tx	ex
0	100	0	0.000	100.0	1465.0	14.650
1	100	0	0.000	100.0	1365.0	13.650
2	100	0	0.000	100.0	1265.0	12.650
3	100	18	18.000	91.0	1165.0	12.802
4	82	5	6.098	79.5	1074.0	13.509
5	77	4	5.195	75.0	994.5	13.260
6	73	6	8.219	70.0	919.5	13.136
7	67	3	4.478	65.5	849.5	12.969
8	64	4	6.250	62.0	784.0	12.645
9	60	3	5.000	58.5	722.0	12.342
10	57	2	3.509	56.0	663.5	11.848
11	55	1	1.818	54.5	607.5	11.147
12	54	6	11.111	51.0	553.0	10.843
13	48	2	4.167	47.0	502.0	10.681
14	46	2	4.348	45.0	455.0	10.111
15	44	2	4.545	43.0	410.0	9.535
16	42	4	9.524	40.0	367.0	9.175
17	38	4	10.526	36.0	327.0	9.083
18	34	3	8.824	32.5	291.0	8.954
19	31	3	9.677	29.5	258.5	8.763
20	28	0	0.000	28.0	229.0	8.179
21	28	0	0.000	28.0	201.0	7.179
22	28	0	0.000	28.0	173.0	6.179
23	28	0	0.000	28.0	145.0	5.179
24	28	7	25.000	24.5	117.0	4.776
25	21	0	0.000	21.0	92.5	4.405
26	21	1	4.762	20.5	71.5	3.488
27	20	2	10.000	19.0	51.0	2.684
28	18	6	33.333	15.0	32.0	2.133
29	12	5	41.667	9.5	17.0	1.789
30	7	4	57.143	5.0	7.5	1.500
31	3	2	66.667	2.0	2.5	1.250
32	1	1	100.000	0.5	0.5	1.000

Table-3.4: Age specific life table of *P. xylostella* on Field Man

x	*lx*	*dx*	*100qx*	*Lx*	*Tx*	*ex*
0	100	0	0.000	100.0	1857.0	18.570
1	100	0	0.000	100.0	1757.0	17.570
2	100	0	0.000	100.0	1657.0	16.570
3	100	13	13.000	93.5	1557.0	16.652
4	87	3	3.448	85.5	1463.5	17.117
5	84	2	2.381	83.0	1378.0	16.602
6	82	4	4.878	80.0	1295.0	16.188
7	78	3	3.846	76.5	1215.0	15.882
8	75	2	2.667	74.0	1138.5	15.385
9	73	2	2.740	72.0	1064.5	14.785
10	71	2	2.817	70.0	992.5	14.179
11	69	4	5.797	67.0	922.5	13.769
12	65	5	7.692	62.5	855.5	13.688
13	60	0	0.000	60.0	793.0	13.217
14	60	0	0.000	60.0	733.0	12.217
15	60	1	1.667	59.5	673.0	11.311
16	59	3	5.085	57.5	613.5	10.670
17	56	3	5.357	54.5	556.0	10.202
18	53	0	0.000	53.0	501.5	9.462
19	53	0	0.000	53.0	448.5	8.462
20	53	4	7.547	51.0	395.5	7.755
21	49	1	2.041	48.5	344.5	7.103
22	48	5	10.417	45.5	296.0	6.505
23	43	6	13.953	40.0	250.5	6.263
24	37	6	16.216	34.0	210.5	6.191
25	31	4	12.903	29.0	176.5	6.086
26	27	0	0.000	27.0	147.5	5.463
27	27	0	0.000	27.0	120.5	4.463
28	27	0	0.000	27.0	93.5	3.463
29	27	6	22.222	24.0	66.5	2.771
30	21	7	33.333	17.5	42.5	2.429
31	14	4	28.571	12.5	25.0	2.000
32	11	4	36.364	9.0	12.5	1.389
33	7	1	14.286	3.5	3.5	1.000

Tabl-3.5: Age specific life table of *P. xylostella* on Golden Acre

x	*lx*	*dx*	*100qx*	*Lx*	*Tx*	*ex*
0	100	0	0.000	100.0	2416.0	24.160
1	100	0	0.000	100.0	2316.0	23.160
2	100	0	0.000	100.0	2216.0	22.160
3	100	10	10.000	95.0	2116.0	22.274
4	90	3	3.333	88.5	2021.0	22.836
5	87	3	3.448	85.5	1932.5	22.602
6	84	2	2.381	83.0	1847.0	22.253
7	82	2	2.439	81.0	1764.0	21.778
8	80	1	1.250	79.5	1683.0	21.170
9	79	4	5.063	77.0	1603.5	20.825
10	75	1	1.333	74.5	1526.5	20.490
11	74	0	0.000	74.0	1452.0	19.622
12	74	2	2.703	73.0	1378.0	18.877
13	72	1	1.389	71.5	1305.0	18.252
14	71	1	1.408	70.5	1233.5	17.496
15	70	2	2.857	69.0	1163.0	16.855
16	68	0	0.000	68.0	1094.0	16.088
17	68	1	1.471	67.5	1026.0	15.200
18	67	2	2.985	66.0	958.5	14.523
19	65	2	3.077	64.0	892.5	13.945
20	63	0	0.000	63.0	828.5	13.151
21	63	0	0.000	63.0	765.5	12.151
22	63	0	0.000	63.0	702.5	11.151
23	63	0	0.000	63.0	639.5	10.151
24	63	3	4.762	61.5	576.5	9.374
25	60	0	0.000	60.0	515.0	8.583
26	60	0	0.000	60.0	455.0	7.583
27	60	0	0.000	60.0	395.0	6.583
28	60	0	0.000	60.0	335.0	5.583
29	60	0	0.000	60.0	275.0	4.583
30	60	8	13.333	56.0	215.0	3.839
31	52	5	9.615	49.5	159.0	3.212
32	47	4	8.511	45.0	109.5	2.433
33	43	15	34.884	35.5	64.5	1.817
34	28	13	46.429	21.5	29.0	1.349
35	15	15	100.000	7.5	7.5	1.000

Table-3.6: Age specific life table of *P. xylostella* on Diamond Express

x	lx	dx	$100qx$	Lx	Tx	ex
0	100	0	0.000	100.0	2675.0	26.750
1	100	0	0.000	100.0	2575.0	25.750
2	100	0	0.000	100.0	2475.0	24.750
3	100	7	7.000	96.5	2375.0	24.611
4	93	2	2.151	92.0	2278.5	24.766
5	91	2	2.198	90.0	2186.5	24.294
6	89	1	1.124	88.5	2096.5	23.689
7	88	0	0.000	88.0	2008.0	22.818
8	88	2	2.273	87.0	1920.0	22.069
9	86	2	2.326	85.0	1833.0	21.565
10	84	1	1.190	83.5	1748.0	20.934
11	83	2	2.410	82.0	1664.5	20.299
12	81	0	0.000	81.0	1582.5	19.537
13	81	0	0.000	81.0	1501.5	18.537
14	81	2	2.469	80.0	1420.5	17.756
15	79	1	1.266	78.5	1340.5	17.076
16	78	0	0.000	78.0	1262.0	16.179
17	78	2	2.564	77.0	1184.0	15.377
18	76	1	1.316	75.5	1107.0	14.662
19	75	2	2.667	74.0	1031.5	13.939
20	73	0	0.000	73.0	957.5	13.116
21	73	0	0.000	73.0	884.5	12.116
22	73	3	4.110	71.5	811.5	11.350
23	70	0	0.000	70.0	740.0	10.571
24	70	0	0.000	70.0	670.0	9.571
25	70	0	0.000	70.0	600.0	8.571
26	70	0	0.000	70.0	530.0	7.571
27	70	5	7.143	67.5	460.0	6.815
28	65	0	0.000	65.0	392.5	6.038
29	65	0	0.000	65.0	327.5	5.038
30	65	7	10.769	61.5	262.5	4.268
31	58	5	8.621	52.5	201.0	3.829
32	47	6	12.766	44.0	148.5	3.375
33	41	8	19.512	37.0	104.5	2.824
34	33	10	30.303	28.0	67.5	2.411
35	23	9	39.130	18.5	39.5	2.135
36	14	5	35.714	11.5	21.0	1.826
37	9	4	44.444	7.0	9.5	1.357
38	5	5	100.000	2.5	2.5	1.000

Table- 3.7: Fecundity table of *P. xylostella* on Pusa Bold

Pivotal age (Day) x	Age specific female survivorship (lx)	Fecundity (mx)	$lx.mx$	$lxmx.x$	Value of $e^{-rmx} l_x.m_x$ Where r_m = 0.1215	% Constitution of each group towards 'r'
0.50-24.5	Immature Stage					
24.5-25.5	Preoviposition Period					
25.5	0.46	22.61	10.40	265.22	0.461	46.11
26.5	0.46	11.08	5.09	135.00	0.200	19.99
27.5	0.46	7.75	3.57	98.04	0.124	12.38
28.5	0.46	6.88	3.16	90.13	0.097	9.72
29.5	0.46	5.06	2.33	68.66	0.063	6.33
30.5	0.33	4.75	1.57	47.81	0.038	3.77
31.5	0.21	2.89	0.61	19.12	0.013	1.29
32.5	0.12	2.55	0.31	9.95	0.006	0.58
SUM		63.57	27.03	733.92	1.000	100.00

Table-3.8: Fecundity table of *P. xylostella* on Varuna

Pivotal age (Day) x	Age specific female survivorship (lx)	Fecundity (mx)	$lx.mx$	$lxmx.x$	Value of $e^{-rmx} l_x.m_x$ Where r_m = 0.0744	% Constitution of each group towards 'r'
0.50-24.5	Immature Stage					
24.5-25.5	Preoviposition Period					
25.5	0.16	16.25	2.60	66.30	0.39	39.05
26.5	0.16	11.06	1.77	46.89	0.25	24.67
27.5	0.16	6.61	1.06	29.08	0.14	13.69
28.5	0.16	6.08	0.97	27.70	0.12	11.68
29.5	0.12	5.25	0.63	18.59	0.07	7.03
30.5	0.09	4.25	0.38	11.67	0.04	3.96
31.5	0.07	3.75	0.26	8.27	0.03	2.52
32.5	0.04	2.63	0.11	3.41	0.01	0.94
SUM		55.87	7.78	211.91	1.00	100.00

Table-3.9: Fecundity table of *P. xylostella* on Pusa Bahar

Pivotal age (Day) x	Age specific female survivorship (lx)	Fecundity (mx)	*lx.mx*	*lxmx.x*	Value of $e^{-rmx} l_x.m_x$ Where r_m = 0.0813	% Constitution of each group towards 'r'
0.50-24.5	Immature Stage					
24.5-25.5	Preoviposition Period					
25.5	0.21	15.25	3.20	81.66	0.403	40.28
26.5	0.21	9.90	2.08	55.09	0.241	24.11
27.5	0.20	7.75	1.55	42.63	0.166	16.57
28.5	0.18	5.63	1.01	28.86	0.100	9.98
29.5	0.12	5.12	0.61	18.11	0.056	5.58
30.5	0.07	4.78	0.33	10.21	0.028	2.80
31.5	0.03	2.75	0.08	2.60	0.006	0.64
32.5	0.01	1.25	0.01	0.41	0.001	0.09
SUM		52.42	8.89	239.56	1.000	100.00

Table-3.10: Fecundity table of *P. xylostella* on Field Man

Pivotal age (Day) x	Age specific female survivorship (lx)	Fecundity (mx)	*lx.mx*	*lxmx.x*	Value of $e^{-rmx} l_x.m_x$ Where r_m = 0.1090	% Constitution of each group towards 'r'
0.50-24.5	Immature Stage					
24.5-25.5	Preoviposition Period					
25.5	0.31	22.68	7.03	179.29	0.428	42.76
26.5	0.27	16.14	4.36	115.48	0.237	23.75
27.5	0.27	8.78	2.37	65.19	0.116	11.57
28.5	0.27	6.98	1.88	53.71	0.082	8.24
29.5	0.27	6.12	1.65	48.75	0.065	6.48
30.5	0.21	5.75	1.21	36.83	0.042	4.24
31.5	0.14	3.95	0.55	17.42	0.017	1.74
32.5	0.11	2.80	0.31	10.01	0.009	0.87
33.5	0.07	2.00	0.14	4.69	0.004	0.35
SUM		75.20	19.50	531.36	1.000	100.00

Table-3.11: Fecundity table of *P. xylostella* on Golden Acre

Pivotal age (Day) x	Age specific female survivorshi (lx)	Fecundity (mx)	$lx.mx$	$lxmx.x$	Value of $e^{-rmx} l_x.m_x$ Where r_m = 0.1432	% Constitution of each group towards 'r'
0.50-24.5	Immature Stage					
24.5-25.5	Preoviposition Period					
25.5	0.60	24.75	14.85	378.68	0.385	38.54
26.5	0.60	17.63	10.58	280.32	0.238	23.79
27.5	0.60	11.10	6.66	183.15	0.130	12.98
28.5	0.60	8.30	4.98	141.93	0.084	8.41
29.5	0.60	7.25	4.35	128.33	0.064	6.37
30.5	0.52	6.63	3.45	105.07	0.044	4.37
31.5	0.47	5.75	2.70	85.13	0.030	2.97
32.5	0.43	4.90	2.11	68.48	0.020	2.01
33.5	0.28	2.75	0.77	25.80	0.006	0.64
34.5	0.15	1.50	0.23	7.76	0.002	0.16
SUM		90.56	49.67	1371.08	1.000	100.00

Table-3.12: Fecundity table of *P. xylostella* on Diamond Express

Pivotal age (Day) x	Age specific female survivorshi (lx)	Fecundity (mx)	$lx.mx$	$lxmx.x$	Value of $e^{-rmx} l_x.m_x$ Where r_m = 0.0483	% Constitution of each group towards 'r'
0.50-26.5	Immature Stage					
26.5-27.5	Preoviposition Period					
27.5	0.65	26.84	17.45	479.77	0.348	34.75
28.5	0.65	22.67	14.74	419.96	0.255	25.46
29.5	0.65	16.56	10.76	317.54	0.161	16.13
30.5	0.58	13.75	7.98	243.24	0.104	10.36
31.5	0.47	10.86	5.10	160.78	0.058	5.75
32.5	0.41	9.73	3.99	129.65	0.039	3.90
33.5	0.33	7.93	2.62	87.67	0.022	2.22
34.5	0.23	5.63	1.29	44.67	0.010	0.95
35.5	0.14	4.79	0.67	23.81	0.004	0.43
36.5	0.09	3.21	0.29	10.54	0.002	0.16
37.5	0.05	2.08	0.10	3.90	0.000	0.05
SUM		124.05	64.99	1921.53	1.000	100.00

Table -3.13: Life indices of *P. xylostella* on *Brassica* hosts

Host plant	*pf*	*Ro*	r_m	λ	T_c	τ	*DT*
Pusa Bold	63.57b	27.03c	0.043d	1.044b	27.15a	32.99a	6.94b
Varuna	55.87a	7.78a	0.027a	1.027a	27.24a	32.10a	11.15e
Pusa Bahar	52.42a	8.89a	0.029b	1.029a	26.95a	32.95a	10.45d
Field Man	75.20c	19.50b	0.038c	1.039b	27.25a	34.04b	7.94c
Golden Acre	90.56d	49.67d	0.049d	1.050c	27.60b	34.97c	6.21a
Diamond Express	124.05e	64.99e	0.048d	1.049bc	29.57c	38.01d	6.31a
LSD (P= 0.05)	4.60	2.15	0.0017	0.010	0.595	0.7820	0.644

Similar alphabets are non significant at 0.05 level by DMRT

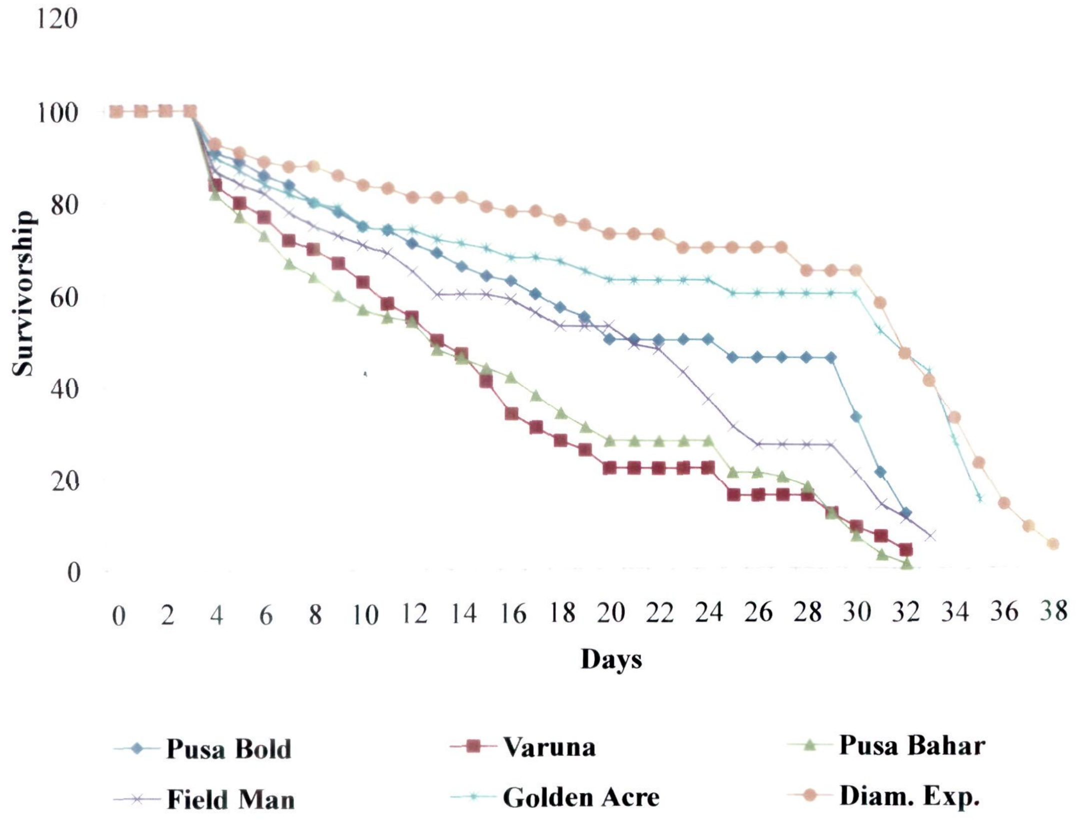


Fig: 3.1. Survivorship of *P. xylostella* on *Brassica* hosts

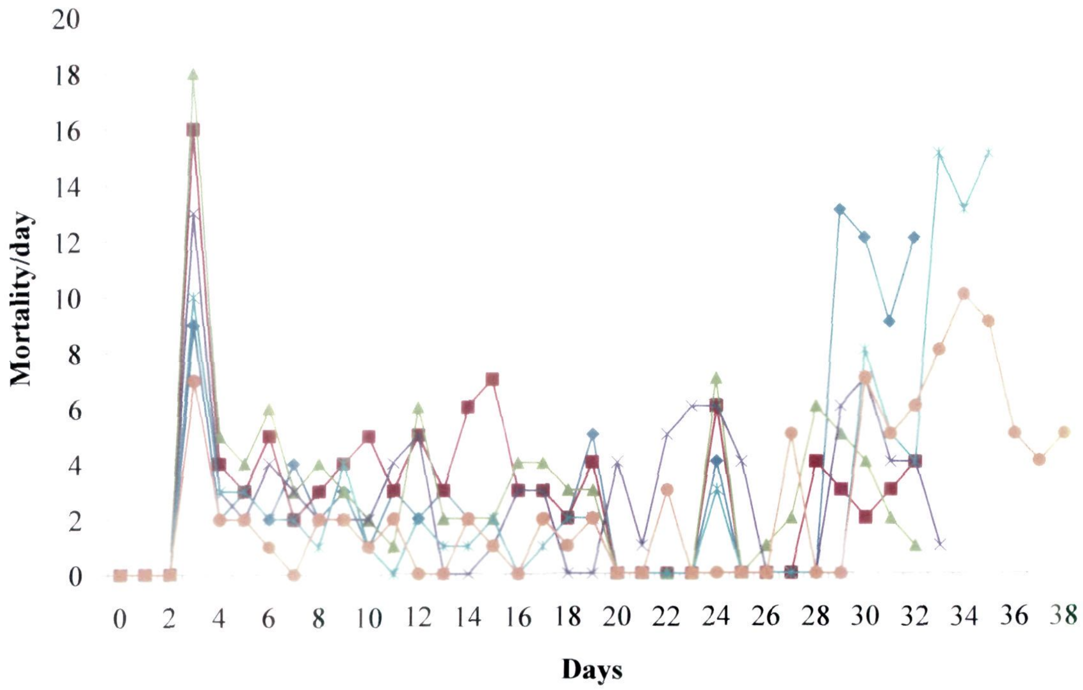


Fig: 3.2. Mortality of *P. xylostella* on *Brassica* hosts

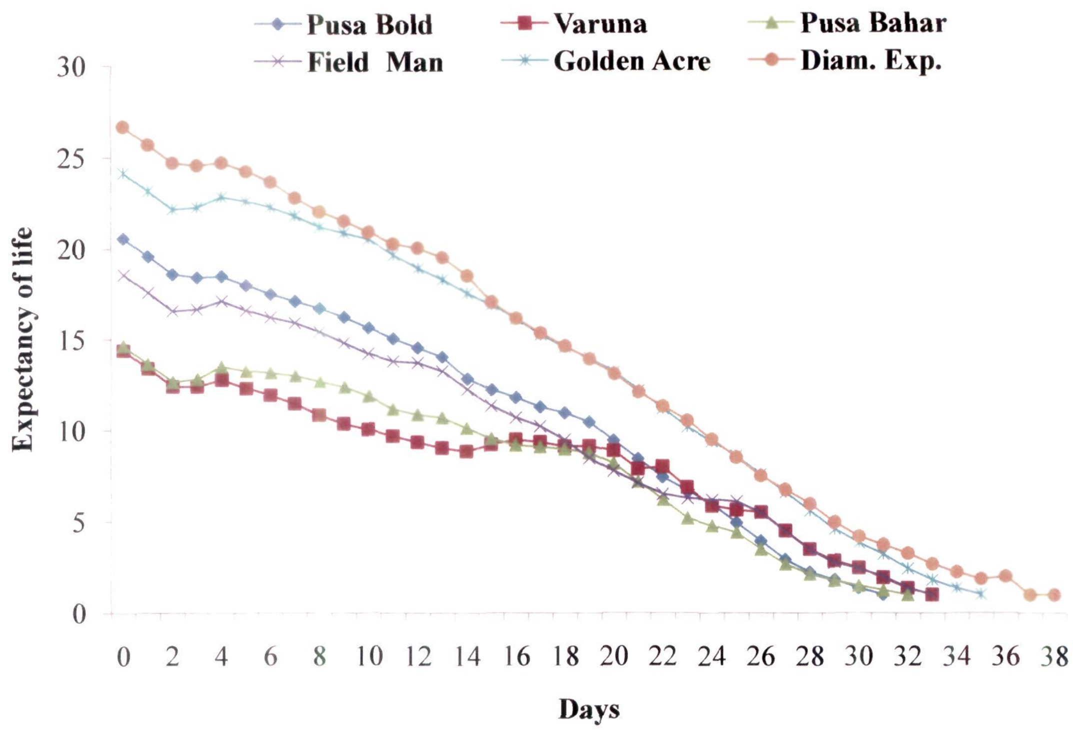


Fig: 3.3. Expectancy of life of *P. xylostella* on *Brassica* hosts

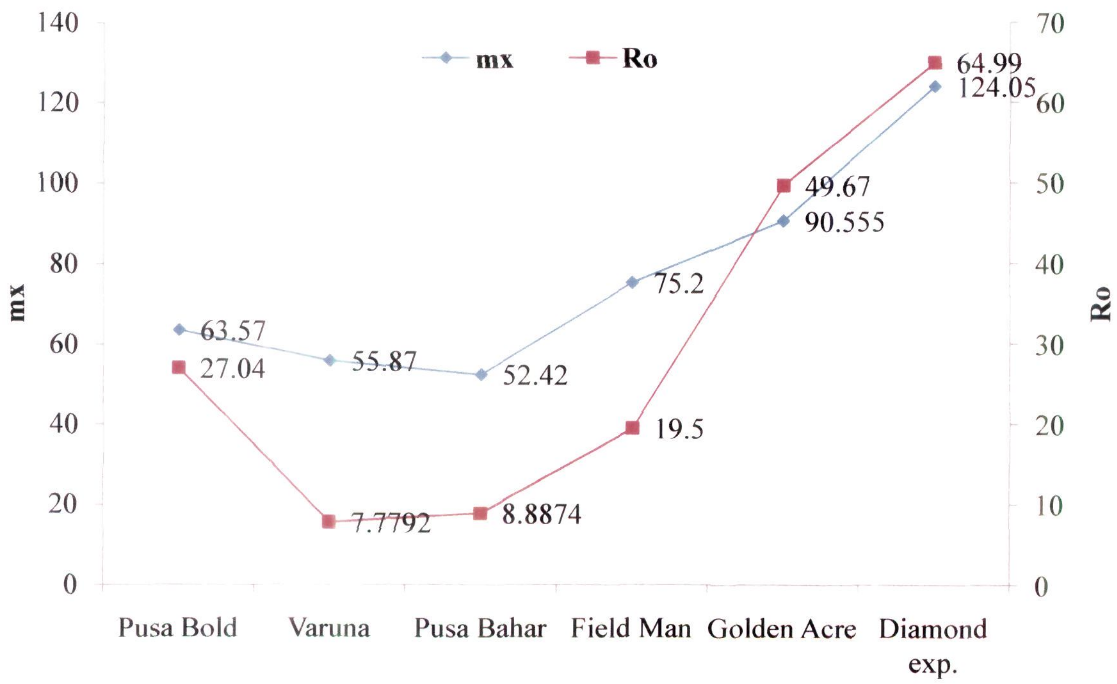


Fig: 3.4. Fecundity (mx) and net reproductive rate (Ro) of *P. xylostella* on *Brassica* hosts

4. Studies on the management of *P. xylostella* on cabbage:

a. Effect of intercropping on the incidence of *P. xylostella* on cabbage in relation to its parasites:

Intercropping with other crops to be grown with sole crop is a common practice in many parts of the country and has beneficial effect in reducing the insec pests damage (Karel *et al.*, 1982). Gautam (1995) has also emphasized the need for intercropping in commercial crops to overcome the problem of insect pests and reduction in pesticide use. Intercropping provides an ecological approach in pest management that affects the pest by microclimate through changes in crop canopies (Bach and Tabashnik, 1990; Wu *et al.*, 1999) and increase natural enemies (Risch, 1981, Khan *et al.*, 1997).

Intercrops, viz., radish, carrot, tomato, garlic, cumin, fennel, coriander, berseem and marigold have significantly/non significantly affected the infestation of *P. xylostella* on cabbage during successive growth stages of the crop. A significantly higher DBM population was recorded on cabbage only (mono crop) than cabbage intercropped with other plants and also found variation in two successive cropping years of 2007-08 and 2008-09. Population of *P. xylostella* on cabbage intercropped with different plants was substantially higher in 2007-08 than in 2008-09 (Table 4.9a).

30-days old seedling of cabbage was transplanted with spacing of 60x45 cm in a ratio of 15:1, 15:2, 25:1 and 25:2 of sole and intercrop. Results showed that effect of intercrop is significantly differed on the incidence as well as lines of sole and intercrops. 15:1 intercrop is significantly/non significantly less effective than 15:2 ratio and in the same manner 25:1 ratio of intercrop is less effective than 25:2 ratio of intercrop. In a control treatment (only cabbage) where the population of larvae and pupae was found to be increasing from 10 to 70 DAP. This population was found to be higher than other treatments. Cabbage intercropped with tomato (15:2 ratio), was superior followed by garlic, cumin, fennel and coriander (Table-4.1-4.8). The data (Table-4.1 to 4.2) showed that when spacing of cabbage (50x40cm) is reduced then it is more likely to be attacked by *P. xylostella* and population of larvae and pupae/plant was found to be higher on these plants in comparison to spacing of 60x45cm. It was also found that there was an overall increase in the incidence of *P. xylostella* (Table-4.5 to 4.6).

The result (Table-4.3 to 4.4) showed that extending the date of planting of cabbage by 10 days means 40 days old seedling holds lesser number of larvae and pupae of *P.*

xylostella. 15:2 ratio for sole and intercrop is significantly /non significantly more effective than 15:1 ratio and similarly 25:2 ratio is more effective than 25:1 ratio. Tomato has significantly deterred the colonization of *P. xylostella* as compared to other treatments while, garlic, cumin, fennel and coriander was also more effective than radish, carrot, berseem and marigold in 2007-08 and 2008-09 (Table-4.1-4.8).

Population of *P. xylostella* is increased when spacing (50x40 cm) is decreased A combination of ratios did not differ on the incidence of *P. xylostella* on radish, carrot, tomato, fennel, and considerably varies in other combinations of ratios. The damage incidence of *P. xylostella* was less on tomato (Plate.3A) intercrop than others. It was also found that garlic (Plate.2A), cumin, fennel (Plate.2B) and coriander (Plate.1A) is more effective intercrop than radish, carrot, berseem and marigold (Plate.3B) during both the cropping years of 2007-08 and 2008-09 (Table-4.9a). Population of *P. xylostella* increases from 10 to 70 DAP then gradually decreases up to harvesting of the crop during both years. Peak population of *P. xylostella* was observed at 70 DAP on cabbage in 2008-09.

Parasitisation was significantly/non significantly differed in intercropping systems (Table-4.9b). Higher parasitisation was recorded in 30-days old seedling of cabbage than 40-days old seedling and in 60x45 cm spacing than 50x40cm and also in 15:1 ratio than 15:2 during both cropping years. Similarly 25:1 ratio attracted more number of parasitoids than 25:2 ratios in both the seedling stages and in all the spacing schedules. Although, lowest rate of parasitisation was found in cabbage plots only that ranged between 6.63 to 7.95 and 5.17 to 7.38 percent in 2007-08 and 2008-09, respectively. Significantly highest parasitisation was observed in cabbage + tomato intercrop (23.64 to 60.71 percent) as compared to other cropping system during both years of study. 54.23 percent of larvae and pupae of *P. xylostella* were parasitized in fennel cropping system in 15:1 ratio with spacing of 60x45 cm when 40-days old seedling of cabbage was transplanted in 2007-08 (Table-4.10, Fig. 4) and 54.93 percent parasitisation was recorded in cumin cropping system in 15:2 ratio with spacing of 50x40 cm in 40-days old seedling of cabbage in 2008-09 (Table-4.10, Fig. 4). Cabbage + berseem cropping system attracted a considerably lower number of parasites as compared to other intercropping system. However, occurrence of parasitoids in cabbage intercropped with garlic, cumin, fennel and coriander was significantly higher as compared to radish, carrot, berseem and marigold cropping system (Table-4.10). *C. plutellae* was observed dominant larval parasitoids in the experimental field during both the years. Although, *O. Sokolowskii*, a pupal parasitoid was also found but few in number.

Analyzed results (Table-4.11-4.18) showed that yield of cabbage is significantly (P<0.05) differed in different intercropping systems and also in relation to spacing and growth stages of seedling of cabbage during both years of study. The highest yield increase was in a range of 47.17 to 61.34 q^{-h} which was produced in cabbage + tomato) cropping system and the lowest i.e. 6.30 to 15.00 q^{-h} in cabbage + marigold as compared to cabbage alone. 40-days old seedling of cabbage when planted produced greater yield than 30-days old in all ratios and spacing schedules during both the years. Spacing of 60x45 cm with a ratio of 15:2 (cabbage + intercrops) produced higher yield of sole and intercrops than that ratio of 15:1 and also on the same way 25:2 produced maximum yield rather than 25:1. Cabbage + tomato cropping system has produced greater yield (265.70 q^{-h}) in 15:2 ratio than 15:1 (263.42 q^{-h}) and 258.77 q^{-h} in 25:2 ratio than 25:1 (258.27 q^{-h}) (Table-4.13) in 40-days old seedling of cabbage. While, it was recorded as 264.61 q^{-h} in 15:2 ratio than that of 15:1 (261.35 q^{-h}) and 256.15 q^{-h} in 25:2 ratio than 25:1 (255.87 q^{-h}) (Table-4.11) in 30-days old seedling of cabbage with 60x45 cm of spacing but comparatively lower yield was recorded in 30-days old seedling of cabbage with 50x40 cm spacing (Table-4.12) in 2007-08. Whereas, 261.84 q^{-h} was produced in 15:2 ratio than in 15:1 (260.51 q^{-h}) and 255.34 q^{-h} was recorded in 25:2 ratio than 25:1 (254.75 q^{-h}) (Table-4.17) in 40-days old seedling of cabbage with 60x45 cm spacing. Although, 249.08 q^{-h} was recorded in 15:2 ratio than 15:1 (248.65 q^{-h}) and 245.27 q^{-h} in 25:2 ratio than 25:1 (244.35 q^{-h}) (Table-4.16) in 30-days old seedling of cabbage with 50x40 cm spacing and 260.39 q^{-h} was recorded in 15:2 ratio than 15:1 (259.28 q^{-h}), similarly 253.77 q^{-h} was recorded in 25:2 ratio than 25:1 (253.40 q^{-h}) (Table-4.15), respectively in 2008-09. Minimum yield was recorded on cabbage + marigold cropping system in relation to stage of seedling, ratio and spacing. Maximum benefit in terms of rupees was estimated on cabbage + tomato cropping system i.e. Rs. 46440/- in 40-days old seedling of cabbage with 60x45cm spacing and 15:2 ratio during 2008-09. While, it was estimated as Rs. 40870/- in 30-days old seedling of cabbage with the same spacing and ratio in 2007-08 as compared to other cropping system (Table- 4.11 and 4.17). Cumin, fennel, garlic and coriander intercrops offered greater additional return as compared to radish, carrot, berseem and marigold during both years of study. Comparatively higher yield was recorded in 2007-08 than in 2008-09.

Weather parameters are significantly/non significantly, positively/negatively correlated in both years of study (Table-4.19 and 4.20). The maximum and minimum temperature, average humidity and rainfall is non significantly (positively/negatively) correlated with ratios and spacing and both seedling stages during both seasons except maximum temperature in 40-days old seedling of cabbage with 25:1 and 25:2 and 60x45 cm of spacing, was significantly negative in 2007-08. The minimum temperature was also substantially affected the population of *P. xylostella* in 2007-08 and there was negligible rainfall in experimental period of 2007-08. In 2008-09 rainfall substantially affected the population of *P. xylostella.*

Environmental conditions caused a significant/non significant effect on the perpetuation of *C. plutellae* during both 2007-08 and 2008-09. Maximum and minimum temperature significantly ($P < 0.01$, $P < 0.05$) enhanced the population of *Cotesia* in 30 and 40-days old seedling of cabbage. Weater parameters substantially affected the population of *C. plutellae* in 2008-09 (Table-4.21-4.22).

Intercrops have significantly ($P<0.05$) affected the infestation of *P. xylostella* during the two cropping years of 2007-08 and 2008-09. Tomato intercrop was found to be considerably more effective against *P. xylostella* than that of other intercrops where the yield and net return was significantly greater than cabbage (sole only) and other intercrops also. Since the yield increase in cabbage + tomato intercrop is in a range of 47.17 to 61.34 q^{-h} (24.46-30.18 percent), which is greater as compared to cabbage (only monoculture) and other intercrops. Whereas, Jolliffe (1997) recorded 12-13 percent greater yield in diculture than that of monoculture. AVRDC, Taiwan recommended that garlic and tomato may be intercropped with cabbage at the same time or 2, 4 weeks earlier, garlic reduced infestation of *P. xylostella* more effectively than tomato in all evaluations (Anonymous, 1985). Chelliah and Srinivasan (1986) reported that intercropping with tomato planted 30 days earlier than cabbage reduced larval damage of *P. xylostella* significantly. However, Talekar *et al.* (1986) incorporated intercropping in the integrated management of *P. xylostella* with tomato, dill, garlic, safflower, oats and barley and found that these crops reduced the damage by *P. xylostella* to cabbage. They also mentioned that application of tomato leaf extract to cabbage significantly reduced oviposition by *P. xylostella* on treated surfaces. Significant reductions were observed in the larvae of *P. xylostella* and *C. binotalis* when cabbages were planted 30 days after tomatoes and to a lesser extent when they were planted 15 days after the tomatoes in comparison to cabbages alone (Srinivasan and Veeresh, 1986).

Cabbage grown with tomatoes had less number of larvae of diamondback moth and higher rates of parasitism by *C. Plutellae* (Kurdjumov) than cabbage grown in monoculture (Bach and Tabashnik, 1990). It was also observed in present study that parasitization in cabbage + tomato cropping system is higher that ranged from 23.64 to 60.71 percent as compared to cabbage alone. The occurrence of parasites in cabbage intercropped with garlic, cumin, fennel and coriander is also higher than that of radish, carrot, berseem and marigold. While, 54.23 percent of larvae and pupae of *P. xylostella* were parasitized in fennel cropping system. Mosiane *et al.* (2003) reported that *C. plutellae* (Kurdjumov) was the most abundant parasitoid throughout the year and accounted for 55 percent of total parasitization. Khan *et al.* (1991) grown cabbage intercropped with mustard (*Sinapis alba*)and reported that the number of insecticide applications against diamondback moth (*P. xylostella*) can be reduced from 25 to 8 with a considerable yield increase and costs reduction.

Tomato intercrop reduced the infestation of *P. xylostella* on cabbage by about 36 percent because tomato contains natural inhibiting chemical but there is no significant reduction in damage (Facknath, 1997, Buranday and Raros, 1973 and Sivapragasam *et al,* 1982) while, Kandoria *et al.* (1999) observed a significant reduction in the infestation of *P. xylostella* when cauliflower intercropped with tomato and also parasitoids regulated the larval stage. Dill and garlic have been reported to act as repellent against *P. xylostella* (Buranday and Raros, 1973, Srinivasan, 1984, Talekar *et al.*, 1986). While, confusing olfactory and visual cues received from the non host plants, leading to disruption of mating, are believed to be partly responsible for reduction in larval number. In an open field intercropping experiment, while cabbage grown in high clover, *Trifolium paratense* received fewer eggs of *P. xylostella* than in monoculture (Asman *et al.*, 2001) suggested that the clover visually camouflaged the host plants and supported the disruptive crop hypotheses. Contrary to the technical report of AVRDC, Taiwan has suggested that none of 54 crops tested for their utility in intercropping had any significant impact on the population of DBM on cabbage (Anonymous, 1998). Meena and Lal (2002) reported that lucerne was most effective intercrop against *P. xylostella* although; garlic and tomato were also effective in reducing the pest population.

In the present study cumin and fennel intercrops were also effective in reducing the population of *P. xylostella.* Although, similar result was obtained in mustard + fennel which offered a significantly lower number of *L. erysimi* than other combinations (Ali and Ansari, 2008). It was confirmed by Singh and Kothari (1997) that allelochemicals released by fennel may deter the colonization of aphid as well as phenotypic characteristics of fennel inflorescence result in natural cover across the inflorescence of mustard canopy. This arrangement may have reduced the increase in aphid population because it created an effective allelochemical barrier film that may have acted as an alarm pheromone which is in conformity with the results for aphids in wild potato, *Solanum berthaultii* (Gibson and Pickett, 1993).

Table-4.1 Effect of intercropping on the incidence of *P. xylostella* on cabbage (30-days old seedling of cabbage with spacing of 60x45 cm) in 2007-08

Treatments	Ratio	10 DAP	20 DAP	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	80 DAP	90 DAP	Avg. Larvae & Pupae/plant
Radish	15:1	2.75	2.99	3.88	6.23	7.26	8.25	5.65	3.64	3.35	4.89i
	15:2	2.45	2.86	3.25	6.20	7.18	8.11	5.61	3.62	3.25	4.73h
	25:1	3.45	4.59	5.42	6.88	7.49	7.65	7.96	5.85	3.75	5.89k
	25:2	3.21	4.46	5.38	6.47	7.19	7.55	7.93	5.83	3.67	5.74h
Carrot	15:1	2.72	2.45	3.46	5.40	6.45	7.65	4.69	3.25	2.35	4.27f
	15:2	2.71	2.35	3.25	5.32	6.35	7.58	4.65	3.21	2.21	4.18f
	25:1	3.51	4.78	5.33	6.89	7.32	7.89	8.12	5.56	3.45	5.87k
	25:2	3.26	4.58	5.16	6.76	7.21	7.59	7.99	5.50	3.26	5.70j
Tomato	15:1	1.45	2.66	2.78	3.55	4.85	4.25	3.85	2.41	1.34	3.02a
	15:2	1.23	2.63	2.65	3.45	4.81	4.21	3.65	2.39	1.31	2.93a
	25:1	2.45	3.16	3.76	4.19	4.36	4.78	4.98	3.78	2.32	3.75d
	25:2	2.33	3.12	3.62	4.15	4.29	4.56	4.92	3.65	2.25	3.65d
Garlic	15:1	1.74	2.65	3.05	3.78	5.12	4.88	3.88	2.94	2.15	3.35c
	15:2	1.26	2.32	3.91	3.45	5.10	4.78	3.80	2.94	2.13	3.30c
	25:1	2.38	3.68	4.11	4.59	4.66	4.99	5.46	4.25	3.25	4.15f
	25:2	2.32	3.65	4.06	4.51	4.46	4.73	5.43	4.16	3.21	4.06e
Cumin	15:1	1.45	2.79	3.10	3.65	4.56	4.56	3.88	2.56	2.19	3.19b
	15:2	1.26	2.46	3.04	3.58	4.55	4.65	3.54	2.54	2.14	3.08ab
	25:1	2.89	3.41	4.51	4.88	4.85	5.09	5.75	4.13	3.65	4.35g
	25:2	2.46	3.32	4.35	4.75	4.85	5.02	5.73	4.11	3.62	4.25f
Fennel	15:1	1.23	2.55	3.14	3.99	4.87	4.72	4.01	2.97	1.99	3.27c
	15:2	1.25	2.48	3.11	3.69	4.86	4.53	3.95	2.92	1.93	3.19b
	25:1	2.90	3.87	4.76	4.97	5.18	5.49	5.65	3.79	3.16	4.42g
	25:2	2.78	3.65	4.64	4.90	5.13	5.42	5.62	3.74	3.15	4.34g
Coriander	15:1	1.75	2.32	3.16	3.87	4.95	4.62	3.65	2.65	1.77	3.19b
	15:2	1.65	2.22	3.15	3.85	4.90	4.61	3.64	2.63	1.63	3.14b
	25:1	2.65	3.65	3.97	4.43	4.75	5.10	5.48	3.60	2.88	4.06e
	25:2	2.33	3.21	3.94	4.31	4.62	5.06	5.44	3.55	2.81	3.92e
Berseem	15:1	2.88	3.21	4.10	4.90	6.21	7.56	3.83	3.22	2.36	4.25f
	15:2	2.76	3.20	4.06	4.88	6.18	7.49	3.81	3.21	2.34	4.21f
	25:1	3.90	4.89	5.44	6.19	7.45	7.86	8.32	6.28	3.97	6.03l
	25:2	3.45	4.56	5.40	6.13	7.24	7.65	8.23	6.23	3.92	5.87k
Marigold	15:1	1.82	2.45	3.45	3.89	4.66	4.56	3.45	2.88	1.35	3.17b
	15:2	1.83	2.32	3.12	3.80	4.60	4.52	3.40	2.85	1.29	3.08ab
	25:1	3.11	3.96	4.16	4.46	4.75	5.26	5.97	3.91	3.29	4.32g
	25:2	3.09	3.45	4.11	4.26	4.26	5.21	5.92	3.91	3.21	4.16f
Cabbage		5.60	8.90	12.50	16.60	18.80	20.26	21.20	15.60	12.30	14.64m
LSD P=0.05											0.15

Similar alphabets are non significant at 0.05 level by DMRT

DAP-Days after plantation

Avg. = Average

Table-4.2 Effect of intercropping on the incidence of *P. xylostella* on cabbage (30-days old seedling of cabbage with spacing of 50x40 cm) in 2007-08

Treatments	Ratio	10 DAP	20 DAP	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	80 DAP	90 DAP	Avg. Larvae & Pupae/plant
Radish	15:1	3.50	3.66	5.00	5.66	7.50	8.26	10.55	8.25	6.25	6.51g
	15:2	3.25	3.44	4.30	5.33	6.66	6.74	10.45	5.65	4.27	5.57c
	25:1	4.50	6.00	7.23	9.25	9.45	10.12	11.75	8.75	5.66	8.08l
	25:2	4.33	5.33	7.33	9.26	9.32	10.01	11.55	8.41	5.45	7.89k
Carrot	15:1	2.33	3.32	5.00	6.00	7.66	9.33	10.65	9.12	6.55	6.66g
	15:2	2.00	2.66	3.66	5.33	6.00	8.00	9.46	7.24	5.34	5.52c
	25:1	4.00	5.66	6.33	9.66	9.75	10.33	11.45	8.45	5.46	7.90k
	25:2	3.50	4.66	6.33	8.33	9.45	10.66	11.40	8.32	5.32	7.55j
Tomato	15:1	1.25	2.00	2.79	4.26	5.46	6.13	9.45	7.33	7.66	5.15b
	15:2	1.15	1.75	2.15	4.13	5.42	6.05	9.15	7.19	6.33	4.81a
	25:1	1.50	3.66	4.66	5.00	8.66	7.33	9.65	7.88	4.61	5.88d
	25:2	1.54	3.50	4.15	4.66	8.33	6.66	9.23	7.65	4.26	5.55j
Garlic	15:1	2.36	2.66	4.12	5.17	7.09	8.66	10.55	8.14	7.90	6.29f
	15:2	2.13	3.00	3.00	5.00	6.33	7.00	10.22	8.05	6.55	5.70c
	25:1	3.33	4.00	5.66	7.33	10.66	9.33	10.28	9.56	5.24	7.27i
	25:2	3.33	3.66	4.66	6.33	10.58	9.33	10.27	9.47	5.23	6.98h
Cumin	15:1	2.10	3.30	4.00	5.66	8.33	9.66	9.25	8.76	7.46	6.50g
	15:2	2.25	3.00	4.00	4.66	6.66	8.33	9.21	8.45	7.16	5.97e
	25:1	3.00	3.33	5.66	7.66	9.55	9.00	10.78	8.24	5.14	6.93h
	25:2	2.66	3.33	4.00	6.66	9.41	8.50	10.47	8.19	5.11	6.48f
Fennel	15:1	2.33	3.66	5.33	6.33	7.66	9.66	9.90	8.76	7.45	6.79h
	15:2	2.00	3.33	4.00	4.66	5.33	8.00	9.75	8.15	7.25	5.83d
	25:1	3.33	4.66	6.33	8.66	13.33	11.66	10.40	9.56	5.45	8.15lm
	25:2	2.00	3.33	5.33	8.00	12.66	10.66	10.35	9.45	5.13	7.43i
Coriander	15:1	3.00	4.33	5.66	7.66	9.33	10.66	10.88	13.00	13.66	8.69n
	15:2	3.00	4.00	5.00	6.66	8.66	9.66	10.76	11.33	11.66	7.86k
	25:1	2.45	4.25	6.78	8.59	10.26	11.26	11.89	9.56	6.55	7.95k
	25:2	2.46	4.21	6.66	8.42	10.11	11.05	11.55	9.23	6.25	7.77k
Berseem	15:1	3.88	5.26	6.45	7.75	9.25	10.99	12.26	10.59	7.85	8.25m
	15:2	3.75	5.12	6.23	6.45	8.95	10.55	11.21	10.26	7.45	7.77k
	25:1	4.66	6.66	8.33	11.33	12.66	14.50	13.66	9.75	6.16	9.75q
	25:2	4.33	5.33	7.33	9.33	13.50	10.50	15.50	9.66	6.11	9.07o
Marigold	15:1	2.44	2.66	3.33	4.33	6.13	8.13	10.26	9.65	7.25	6.02e
	15:2	2.32	2.52	3.16	4.25	6.06	8.10	10.21	9.52	7.20	5.93de
	25:1	1.66	3.33	5.66	6.33	10.33	10.45	11.88	9.25	6.23	7.24i
	25:2	1.66	2.33	4.33	5.33	9.33	10.42	11.82	9.66	6.21	6.79h
Cabbage		5.12	6.60	8.89	13.65	15.59	17.56	18.59	16.95	15.56	13.17q
LSD P=0.05											0.207

Similar alphabets are non significant at 0.05 level by DMRT

Table-4.3 Effect of intercropping on the incidence of *P. xylostella* on cabbage (40-days old seedling of cabbage with spacing of 60x45 cm) in 2007-08

Treatments	Ratio	10 DAP	20 DAP	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	80 DAP	90 DAP	Avg. Larvae & Pupae/plant
Radish	15:1	2.33	2.55	3.21	5.24	6.45	7.22	5.26	3.56	3.25	4.34e
	15:2	2.11	2.50	3.12	5.02	6.23	7.46	5.21	3.21	3.16	4.22d
	25:1	2.75	2.99	3.88	6.23	7.26	8.25	5.65	3.64	3.35	4.89f
	25:2	2.45	2.86	3.25	6.20	7.18	8.11	5.61	3.62	3.25	4.73f
Carrot	15:1	2.46	2.66	3.12	5.12	6.25	7.55	4.52	3.45	2.12	4.14d
	15:2	2.13	2.49	3.10	5.10	6.21	7.25	4.40	3.12	2.11	3.99d
	25:1	2.72	2.45	3.46	5.40	6.45	7.65	4.69	3.25	2.35	4.27e
	25:2	2.71	2.35	3.25	5.32	6.35	7.58	4.65	3.21	2.21	4.18d
Tomato	15:1	1.26	2.15	2.50	3.21	4.65	4.12	3.65	2.36	1.26	2.80a
	15:2	1.20	2.11	2.41	3.12	4.62	4.09	3.55	2.21	1.22	2.73a
	25:1	1.45	2.66	2.78	3.55	4.85	4.25	3.85	2.41	1.34	3.02b
	25:2	1.23	2.63	2.65	3.45	4.81	4.21	3.65	2.39	1.31	2.93a
Garlic	15:1	1.25	2.43	2.95	3.65	4.99	4.75	3.69	2.68	2.11	3.17b
	15:2	1.18	2.12	2.65	3.25	4.95	4.62	3.62	2.65	2.10	3.02b
	25:1	1.74	2.65	3.05	3.78	5.12	4.88	3.88	2.94	2.15	3.35c
	25:2	1.26	2.32	3.91	3.45	5.10	4.78	3.80	2.94	2.13	3.30c
Cumin	15:1	1.88	2.87	3.09	3.46	4.26	4.25	3.68	2.44	2.16	3.12b
	15:2	1.26	2.55	3.02	3.44	4.23	4.21	3.65	2.40	2.13	2.99b
	25:1	1.45	2.79	3.10	3.65	4.56	4.56	3.88	2.56	2.19	3.19b
	25:2	1.26	2.46	3.04	3.58	4.55	4.65	3.54	2.54	2.14	3.08b
Fennel	15:1	1.25	2.44	3.12	3.88	4.65	4.55	3.98	2.88	1.95	3.19b
	15:2	1.16	2.40	3.10	3.69	4.62	4.78	3.65	2.84	1.56	3.09b
	25:1	1.23	2.55	3.14	3.99	4.87	4.72	4.01	2.97	1.99	3.27b
	25:2	1.25	2.48	3.11	3.69	4.86	4.53	3.95	2.92	1.93	3.19b
Coriander	15:1	1.55	2.78	3.18	3.75	4.89	4.59	3.58	2.25	1.75	3.15b
	15:2	1.52	2.56	3.15	3.65	4.81	4.52	3.51	2.24	1.62	3.06b
	25:1	1.75	2.32	3.16	3.87	4.95	4.62	3.65	2.65	1.77	3.19b
	25:2	1.65	2.22	3.15	3.85	4.90	4.61	3.64	2.63	1.63	3.14b
Berseem	15:1	2.75	3.26	3.98	4.85	6.13	7.26	3.77	3.21	2.31	4.17d
	15:2	2.45	3.24	3.65	4.65	6.12	7.24	3.72	3.16	2.22	4.05d
	25:1	2.88	3.21	4.10	4.90	6.21	7.56	3.83	3.22	2.36	4.25e
	25:2	2.76	3.20	4.06	4.88	6.18	7.49	3.81	3.21	2.34	4.21a
Marigold	15:1	1.78	2.12	3.22	3.65	4.55	4.45	3.12	2.65	1.26	2.98 ab
	15:2	1.70	2.09	3.18	3.62	4.51	4.44	3.10	2.63	1.25	2.95a
	25:1	1.82	2.45	3.45	3.89	4.66	4.56	3.45	2.88	1.35	3.17b
	25:2	1.83	2.32	3.12	3.80	4.60	4.52	3.40	2.85	1.29	3.08b
Cabbage		1.82	2.45	3.45	3.89	4.66	4.56	3.45	2.88	1.35	13.10g
LSD P=0.05											0.247

Similar alphabets are non significant at 0.05 level by DMRT

Table-4.4 Effect of intercropping on the incidence of *P. xylostella* on cabbage (40-days old seedling of cabbage with spacing of 50x40 cm) in 2007-08

Treatments	Ratio	10 DAP	20 DAP	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	80 DAP	90 DAP	Avg. Larvae & Pupae/plant
Radish	15:1	3.21	4.26	5.23	6.75	7.21	7.50	7.89	5.76	3.65	5.72d
	15:2	3.15	4.22	5.21	6.45	7.19	7.45	7.45	5.72	3.54	5.60d
	25:1	3.45	4.59	5.42	6.88	7.49	7.65	7.96	5.85	3.75	5.89d
	25:2	3.21	4.46	5.38	6.47	7.19	7.55	7.93	5.83	3.67	5.74d
Carrot	15:1	3.45	4.89	5.16	6.79	7.18	7.86	7.98	5.45	3.21	5.77d
	15:2	3.21	4.56	5.11	6.75	7.12	7.74	7.63	5.42	3.20	5.64d
	25:1	3.51	4.78	5.33	6.89	7.32	7.89	8.12	5.56	3.45	5.87d
	25:2	3.26	4.58	5.16	6.76	7.21	7.59	7.99	5.50	3.26	5.70d
Tomato	15:1	2.21	3.11	3.76	4.13	4.26	4.48	4.75	3.56	2.21	3.61a
	15:2	2.16	3.05	3.45	4.10	4.23	4.41	4.65	3.41	2.16	3.51a
	25:1	2.45	3.16	3.76	4.19	4.36	4.78	4.98	3.78	2.32	3.75a
	25:2	2.33	3.12	3.62	4.15	4.29	4.56	4.92	3.65	2.25	3.65a
Garlic	15:1	2.31	3.55	3.95	4.42	4.65	4.90	5.16	4.13	3.20	4.03b
	15:2	2.29	3.45	3.65	4.32	4.42	4.82	5.11	4.11	3.18	3.93b
	25:1	2.38	3.68	4.11	4.59	4.66	4.99	5.46	4.25	3.25	4.15c
	25:2	2.32	3.65	4.06	4.51	4.46	4.73	5.43	4.16	3.21	4.06b
Cumin	15:1	2.55	3.22	4.16	4.52	4.75	4.92	5.55	4.02	3.45	4.13bc
	15:2	2.54	3.21	4.12	4.26	4.65	4.83	5.47	4.01	3.44	4.06b
	25:1	2.89	3.41	4.51	4.88	4.85	5.09	5.75	4.13	3.65	4.35c
	25:2	2.46	3.32	4.35	4.75	4.85	5.02	5.73	4.11	3.62	4.25c
Fennel	15:1	2.88	3.74	4.26	4.87	5.06	5.33	5.49	3.78	3.13	4.28c
	15:2	2.56	3.73	4.16	4.85	5.02	5.32	5.45	3.73	3.10	4.21c
	25:1	2.90	3.87	4.76	4.97	5.18	5.49	5.65	3.79	3.16	4.42c
	25:2	2.78	3.65	4.64	4.90	5.13	5.42	5.62	3.74	3.15	4.34c
Coriander	15:1	2.56	3.45	3.89	4.21	4.56	4.96	5.22	3.55	2.75	3.91b
	15:2	2.34	3.24	3.66	4.16	4.26	4.85	5.19	3.51	2.72	3.77a
	25:1	2.65	3.65	3.97	4.43	4.75	5.10	5.48	3.60	2.88	4.06b
	25:2	2.33	3.21	3.94	4.31	4.62	5.06	5.44	3.55	2.81	3.92b
Berseem	15:1	3.88	4.75	5.21	6.13	7.22	7.46	8.11	6.23	3.89	5.88d
	15:2	3.65	4.71	5.22	6.05	7.12	7.26	8.06	6.21	3.82	5.79d
	25:1	3.90	4.89	5.44	6.19	7.45	7.86	8.32	6.28	3.97	6.03e
	25:2	3.45	4.56	5.40	6.13	7.24	7.65	8.23	6.23	3.92	5.87d
Marigold	15:1	3.05	3.75	4.02	4.16	4.69	5.12	5.79	3.85	3.23	4.18c
	15:2	3.04	3.55	4.00	4.11	4.56	5.11	5.73	3.82	3.15	4.12b
	25:1	3.11	3.96	4.16	4.46	4.75	5.26	5.97	3.91	3.29	4.32c
	25:2	3.09	3.45	4.11	4.26	4.26	5.21	5.92	3.91	3.21	4.16c
Cabbage		3.11	3.96	4.16	4.46	4.75	5.26	5.97	3.91	3.29	12.71f
LSD P=0.05											0.31

Similar alphabets are non significant at 0.05 level by DMRT

Table-4.5 Effect of intercropping on the incidence of *P. xylostella* on cabbage (30-days old seedling of cabbage with spacing of 60x45 cm) in 2008-09

Treatments	Ratio	10 DAP	20 DAP	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	80 DAP	90 DAP	Avg. Larvae & Pupae/plant
Radish	15:1	2.89	2.99	3.78	5.55	7.89	9.88	10.21	6.22	5.46	6.10b
	15:2	2.45	2.66	3.55	5.15	7.35	8.55	9.26	6.04	4.26	5.47a
	25:1	3.20	4.26	5.60	6.75	8.16	9.80	10.50	7.25	5.60	6.79b
	25:2	3.11	3.05	5.20	6.42	8.10	9.14	10.22	7.20	5.17	6.40b
Carrot	15:1	2.80	3.45	4.56	5.98	7.75	9.78	10.10	6.11	5.44	6.22b
	15:2	2.50	3.35	4.44	5.80	7.75	9.46	9.96	5.58	5.35	6.02b
	25:1	2.90	3.75	4.89	5.99	8.12	10.25	10.22	6.63	5.89	6.52b
	25:2	2.72	3.60	4.85	5.90	8.10	10.12	10.20	6.20	5.86	6.39b
Tomato	15:1	1.27	2.55	3.15	3.56	4.66	5.23	5.26	4.26	4.12	3.78a
	15:2	1.16	2.35	3.02	3.51	4.36	5.20	5.25	4.22	4.05	3.68a
	25:1	1.85	2.56	3.45	3.78	4.89	5.74	5.72	4.43	4.44	4.10a
	25:2	1.42	2.53	3.40	3.65	4.80	5.50	5.65	4.41	4.40	3.97a
Garlic	15:1	1.62	2.95	3.75	3.99	5.16	5.88	6.56	4.66	4.16	4.30a
	15:2	1.45	2.90	3.60	3.46	5.06	5.66	6.35	4.54	4.11	4.13a
	25:1	1.78	3.25	3.95	4.25	5.55	6.21	6.85	5.12	4.32	4.59a
	25:2	1.72	3.11	3.92	4.15	5.42	6.15	6.42	5.10	4.31	4.48a
Cumin	15:1	2.50	3.66	4.26	5.75	7.66	9.25	10.11	6.66	5.36	6.13b
	15:2	2.46	3.55	4.25	5.65	7.61	9.15	10.08	6.45	5.22	6.05b
	25:1	2.75	3.96	4.75	5.90	8.01	9.45	10.22	6.78	5.45	6.36b
	25:2	2.71	3.75	4.66	5.86	7.95	9.39	10.19	6.67	5.44	6.29b
Fennel	15:1	2.79	3.68	5.66	6.45	8.22	10.25	10.55	7.88	6.66	6.90b
	15:2	2.60	3.45	5.55	6.51	8.15	9.85	10.49	7.45	7.25	6.81b
	25:1	3.13	3.89	5.98	6.79	9.25	10.65	10.86	7.55	7.30	7.27b
	25:2	3.06	3.78	5.78	6.66	9.11	10.45	10.76	7.32	7.28	7.13b
Coriander	15:1	3.54	4.65	5.98	7.88	9.45	10.75	10.89	8.25	6.75	7.57b
	15:2	3.45	4.58	5.76	7.82	9.35	10.63	10.82	8.18	6.67	7.47b
	25:1	3.75	4.88	6.10	7.98	9.65	10.86	11.32	8.49	6.94	7.77b
	25:2	3.55	4.65	6.08	7.96	9.55	10.81	11.22	8.42	6.84	7.68b
Berseem	15:1	3.97	5.69	6.45	7.96	9.45	11.12	11.16	10.45	7.98	8.25c
	15:2	3.88	5.45	6.32	7.58	9.32	11.05	11.15	10.15	7.65	8.06c
	25:1	4.95	6.67	8.75	11.38	12.45	15.45	12.50	10.75	9.58	10.28d
	25:2	4.75	6.62	8.65	11.22	12.36	15.12	12.22	10.45	9.55	10.10d
Marigold	15:1	2.78	3.10	3.45	4.78	6.48	8.79	10.12	8.78	6.25	6.06b
	15:2	2.45	3.04	3.32	4.62	6.42	8.66	9.95	8.61	6.11	5.91b
	25:1	2.15	3.45	5.78	6.76	8.55	9.45	10.25	9.22	6.75	6.93b
	25:2	2.75	2.78	4.79	6.73	8.43	9.12	10.22	9.00	6.45	6.70b
Cabbage		6.45	9.97	15.56	18.65	20.78	23.56	25.25	21.22	18.78	17.80e
LSD P=0.05											1.90

Similar alphabets are non significant at 0.05 level by DMRT

Table-4.6 Effect of intercropping on the incidence of *P. xylostella* on cabbage (30-days old seedling of cabbage with spacing of 50x40 cm) in 2008-09

Treatments	Ratio	10 DAP	20 DAP	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	80 DAP	90 DAP	Avg. Larvae & Pupae/plant
Radish	15:1	3.75	4.15	5.12	5.79	7.90	9.25	10.76	7.86	6.28	6.76c
	15:2	3.64	4.05	5.10	5.55	7.86	9.13	10.55	7.45	6.12	6.61c
	25:1	4.55	6.15	7.45	9.35	9.68	10.47	11.89	9.21	6.19	8.33e
	25:2	4.13	5.65	7.32	9.26	9.62	10.39	11.84	9.13	6.12	8.16e
Carrot	15:1	2.86	3.56	5.64	6.15	7.88	9.45	10.85	9.19	6.59	6.91c
	15:2	2.56	2.88	5.12	5.65	7.54	9.25	10.45	9.11	6.13	6.52b
	25:1	4.05	5.68	6.45	9.78	9.99	10.58	11.56	8.79	6.78	8.18e
	25:2	3.90	5.66	6.41	9.45	9.94	10.99	11.56	8.45	6.13	8.05e
Tomato	15:1	1.50	2.14	2.88	4.56	5.88	6.46	9.78	7.85	5.25	5.14a
	15:2	1.35	2.10	2.45	4.45	5.75	6.35	9.45	7.56	5.12	4.95a
	25:1	1.75	3.89	4.68	5.25	8.98	7.49	9.78	7.88	5.39	6.12b
	25:2	1.70	3.78	4.66	5.14	8.56	7.35	9.62	7.66	5.30	5.97b
Garlic	15:1	2.88	2.94	4.35	5.46	7.31	8.95	10.55	8.42	7.92	6.53b
	15:2	2.65	3.14	4.22	5.35	7.22	8.46	10.46	8.31	7.14	6.33b
	25:1	3.75	4.25	5.68	7.45	10.55	9.45	10.78	9.88	7.98	7.75d
	25:2	3.62	4.19	5.45	7.32	10.51	9.24	10.62	9.74	7.45	7.57d
Cumin	15:1	2.45	3.47	4.35	5.69	8.56	9.88	9.78	8.98	7.78	6.77c
	15:2	2.32	3.34	4.25	4.12	8.11	8.79	9.45	8.45	7.14	6.22b
	25:1	3.15	3.78	5.68	7.68	9.64	9.45	10.88	8.55	7.88	7.41d
	25:2	3.11	3.69	4.66	7.45	9.32	9.11	10.46	8.49	7.42	7.08c
Fennel	15:1	2.78	3.98	5.79	6.78	8.55	10.56	10.45	9.46	6.98	7.26d
	15:2	2.19	3.42	5.13	5.45	7.66	9.45	10.22	9.44	6.25	6.58c
	25:1	3.49	4.38	6.78	8.79	10.25	11.78	10.56	9.55	7.25	8.09e
	25:2	3.12	4.02	6.25	8.44	10.11	11.45	10.49	9.51	6.45	7.76d
Coriander	15:1	3.29	4.76	5.97	8.11	9.88	10.99	11.25	9.85	8.56	8.07e
	15:2	3.02	4.12	5.44	7.56	9.45	10.46	10.56	9.55	8.44	7.62d
	25:1	3.56	4.89	6.88	8.77	10.55	11.35	11.90	9.90	8.79	8.51e
	25:2	3.25	4.35	6.45	8.55	10.22	11.23	11.36	9.56	8.55	8.17e
Berseem	15:1	3.90	5.88	6.79	7.89	9.78	11.25	12.46	10.22	9.88	8.67f
	15:2	3.78	5.75	6.45	7.23	9.25	9.56	11.78	9.56	8.52	7.99e
	25:1	4.88	6.75	8.71	11.45	12.88	14.62	13.99	10.58	9.95	10.42h
	25:2	4.45	6.14	8.12	9.79	12.36	11.25	14.56	9.95	8.55	9.46g
Marigold	15:1	2.78	3.45	4.12	5.25	7.88	8.77	10.45	8.56	7.58	6.54b
	15:2	2.51	3.56	3.75	4.56	7.89	8.56	10.22	8.25	7.29	6.29c
	25:1	2.89	3.78	5.68	6.79	9.78	10.78	11.28	8.79	7.88	7.52d
	25:2	2.58	3.45	4.88	6.11	9.56	10.25	11.12	8.22	7.58	7.08c
Cabbage		7.76	13.43	18.25	21.35	24.36	27.56	28.10	20.26	18.23	19.92i
LSD P=0.05											0.59

Similar alphabets are non significant at 0.05 level by DMRT

Table-4.7 Effect of intercropping on the incidence of *P. xylostella* on cabbage (40-days old seedling of cabbage with spacing of 60x45 cm) in 2008-09

Treatments	Ratio	10 DAP	20 DAP	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	80 DAP	90 DAP	Avg. Larvae & Pupae/plant
Radish	15:1	2.89	3.88	4.56	6.88	8.75	9.41	10.25	8.99	7.88	7.05d
	15:2	2.54	3.44	4.23	6.23	7.99	9.12	9.56	8.25	7.12	6.50c
	25:1	3.16	3.89	4.87	7.45	8.45	10.25	11.45	9.26	7.90	7.41d
	25:2	2.88	3.56	4.23	6.56	8.12	9.57	10.23	9.12	7.42	6.85d
Carrot	15:1	2.78	3.78	4.14	5.69	7.89	8.95	9.95	8.55	8.12	6.65c
	15:2	2.45	3.25	3.56	5.25	7.14	7.88	9.45	8.14	7.56	6.08c
	25:1	2.98	3.89	4.25	5.90	8.11	9.25	10.45	9.45	9.56	7.09d
	25:2	2.85	3.46	3.89	5.49	7.56	8.26	10.35	9.19	8.25	6.59c
Tomato	15:1	1.58	2.78	3.16	3.88	4.78	5.35	5.92	4.58	3.78	3.98a
	15:2	1.35	2.45	2.96	3.56	4.70	4.88	5.56	4.23	3.45	3.68a
	25:1	1.65	2.98	3.39	4.15	5.45	5.87	6.35	4.88	3.89	4.29a
	25:2	1.36	2.69	3.11	3.95	5.15	5.20	6.13	4.35	3.55	3.94a
Garlic	15:1	1.98	3.26	4.44	5.25	6.88	8.45	9.66	8.56	6.77	6.14c
	15:2	1.53	3.11	4.22	4.85	6.25	8.25	9.25	8.22	6.32	5.78c
	25:1	2.25	3.45	4.75	5.76	7.22	9.26	9.78	8.77	6.12	6.37c
	25:2	2.05	3.16	4.23	5.35	7.20	9.12	9.56	8.56	6.10	6.15c
Cumin	15:1	2.45	3.56	4.55	5.65	6.88	8.64	10.22	9.05	7.88	6.54c
	15:2	2.13	3.24	4.32	5.25	6.52	8.36	10.20	8.69	7.45	6.24c
	25:1	2.87	3.88	4.88	5.89	7.12	8.87	10.44	9.25	7.91	6.79d
	25:2	2.32	3.42	4.32	5.67	6.76	8.54	10.25	8.78	7.45	6.39c
Fennel	15:1	1.45	2.68	3.76	4.23	5.45	6.56	7.56	6.47	5.65	4.87b
	15:2	1.36	2.41	3.12	4.12	5.21	6.32	7.21	6.25	5.23	4.58a
	25:1	1.78	2.88	3.78	4.45	5.75	6.89	7.89	6.78	6.12	5.15b
	25:2	1.44	2.65	3.45	4.32	5.42	6.51	7.45	6.23	5.87	4.82
Coriander	15:1	1.78	2.88	3.56	4.12	5.35	6.46	7.44	6.45	5.15	4.80b
	15:2	1.65	2.45	3.31	3.95	5.13	6.22	7.22	6.37	5.11	4.60a
	25:1	1.98	2.94	3.88	4.25	5.65	6.75	7.68	6.80	5.24	5.02b
	25:2	1.72	2.64	3.52	4.15	5.61	6.31	7.42	6.20	5.19	4.75b
Berseem	15:1	2.88	3.56	4.88	5.66	6.75	7.65	9.58	8.25	6.36	6.17c
	15:2	2.56	3.22	4.68	5.23	6.45	7.45	9.24	8.21	6.32	5.93c
	25:1	3.12	3.87	4.99	5.85	6.80	7.88	9.76	8.26	6.54	6.34c
	25:2	2.98	3.42	4.56	5.63	6.55	7.84	9.45	8.14	6.31	6.10c
Marigold	15:1	2.12	2.45	3.65	4.57	5.68	6.45	7.98	6.69	5.89	5.05b
	15:2	1.56	2.23	3.42	4.36	5.61	6.32	7.85	6.32	5.45	4.79b
	25:1	2.25	2.87	3.88	4.87	6.11	6.78	8.96	6.79	5.90	5.38b
	25:2	1.96	2.44	3.46	4.56	5.88	6.33	8.56	6.45	5.59	5.03b
Cabbage		4.88	9.03	13.56	17.78	18.67	21.55	23.62	20.12	18.32	16.39e
LSD P=0.05											0.970

Similar alphabets are non significant at 0.05 level by DMRT

Table-4.8 Effect of intercropping on the incidence of *P. xylostella* on cabbage (40-days old seedling of cabbage with spacing of 50x40 cm) in 2008-09

Treatments	Ratio	10 DAP	20 DAP	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	80 DAP	90 DAP	Avg. Larvae & Pupae/plant
Radish	15:1	3.56	4.79	5.89	7.45	8.56	9.11	10.23	8.59	7.25	7.27f
	15:2	3.31	4.45	5.34	6.89	7.98	8.75	10.05	8.11	6.89	6.86f
	25:1	3.78	4.99	6.35	7.89	8.78	9.57	10.55	8.76	7.45	7.57g
	25:2	3.44	4.58	5.42	7.65	8.58	9.35	10.43	8.23	7.25	7.21f
Carrot	15:1	3.88	5.69	6.54	7.88	8.89	9.68	10.55	8.95	7.68	7.75g
	15:2	3.55	5.45	6.22	7.45	8.53	9.63	10.25	8.53	7.42	7.45g
	25:1	3.97	6.12	6.89	8.56	9.25	9.96	10.88	9.66	8.56	8.21h
	25:2	3.56	3.56	6.75	7.86	8.89	9.78	10.35	8.69	7.73	7.46g
Tomato	15:1	2.36	3.42	3.88	4.25	4.35	4.52	4.78	3.69	2.39	3.74a
	15:2	2.22	3.25	3.55	4.23	4.25	4.45	4.68	3.51	2.25	3.60a
	25:1	2.48	3.54	4.22	4.75	4.99	5.56	6.32	4.25	3.35	4.38b
	25:2	2.34	3.26	3.78	4.45	4.75	4.47	4.69	3.59	2.29	3.74a
Garlic	15:1	2.49	3.88	4.25	4.89	4.98	5.89	6.75	5.69	4.55	4.82c
	15:2	2.32	3.56	3.88	4.56	4.65	4.78	5.98	5.14	4.28	4.35b
	25:1	2.88	4.26	4.69	5.76	6.23	6.96	7.58	5.26	4.75	5.37d
	25:2	2.45	3.75	3.94	4.86	4.78	4.88	6.58	5.16	4.38	4.53b
Cumin	15:1	2.98	3.56	4.75	4.89	5.15	6.25	7.25	6.13	5.26	5.14c
	15:2	2.54	3.21	4.12	4.26	4.65	4.83	5.47	4.01	3.44	4.06ab
	25:1	2.89	3.41	4.51	4.88	4.85	5.09	5.75	4.13	3.65	4.35b
	25:2	2.46	3.32	4.35	4.75	4.85	5.02	5.73	4.11	3.62	4.25b
Fennel	15:1	3.21	3.86	4.88	4.96	5.56	6.45	7.85	5.26	4.25	5.14c
	15:2	3.11	3.50	4.45	4.90	5.42	6.23	7.42	5.02	4.15	4.91c
	25:1	3.45	3.95	5.12	5.46	5.98	6.35	7.90	5.88	4.35	5.38d
	25:2	3.32	3.85	5.02	5.32	5.45	6.32	7.85	5.65	4.25	5.23c
Coriander	15:1	2.78	3.76	3.95	4.45	5.25	5.89	6.78	4.58	3.96	4.60b
	15:2	2.65	3.45	3.85	4.42	5.20	5.74	6.55	4.45	3.90	4.47b
	25:1	2.98	3.88	4.12	4.75	5.56	6.11	6.98	4.68	4.25	4.81c
	25:2	2.66	3.65	3.01	4.63	5.44	6.10	6.90	4.52	4.15	4.56b
Berseem	15:1	4.25	5.23	5.78	6.45	7.32	7.88	8.55	6.45	4.89	6.31e
	15:2	4.18	5.11	5.52	6.32	7.26	7.65	8.35	6.38	4.65	6.16e
	25:1	4.45	5.32	5.98	6.54	7.50	7.94	8.64	6.52	4.93	6.42e
	25:2	4.32	5.26	5.66	6.49	7.42	7.69	6.45	6.43	4.66	6.04e
Marigold	15:1	3.44	3.99	4.78	5.32	5.89	6.68	5.87	5.32	4.76	5.12c
	15:2	3.25	3.85	4.66	5.22	5.55	6.53	5.66	5.22	4.45	4.93c
	25:1	3.62	4.32	4.88	5.65	5.99	6.87	7.11	5.43	4.89	5.42d
	25:2	3.45	4.12	4.67	5.51	5.87	6.75	6.99	5.35	4.65	5.26c
Cabbage		6.05	10.67	14.56	18.68	22.55	23.95	27.62	21.49	20.16	18.41i
LSD P=0.05											0.46

Similar alphabets are non significant at 0.05 level by DMRT

Table-4.9a. Mean population of *P. xylostella* during 2007-08 and 2008-09

Intercrop	Ratio	2007-08				2008-09			
		30-days old seedling		40-days old seedling		30-days old seedling		40-days old seedling	
		A	B	A	B	A	B	A	B
Radish	15:1	4.89i	6.51g	4.34e	5.72d	6.10b	6.76c	7.05d	7.27f
	15:2	4.73h	5.57c	4.22d	5.60d	5.47a	6.61c	6.50c	6.86f
	25:1	5.89k	8.08l	4.89f	5.89d	6.79b	8.33e	7.41d	7.57g
	25:2	5.74h	7.89k	4.73f	5.74d	6.40b	8.16e	6.85d	7.21f
Carrot	15:1	4.27f	6.66g	4.14d	5.77d	6.22b	6.91c	6.65c	7.75g
	15:2	4.18f	5.52c	3.99d	5.64d	6.02b	6.52b	6.08c	7.45g
	25:1	5.87k	7.90k	4.27e	5.87d	6.52b	8.18e	7.09d	8.21h
	25:2	5.70j	7.55j	4.18d	5.70d	6.39b	8.05e	6.59c	7.46g
Tomato	15:1	3.02a	5.15b	2.80a	3.61a	3.78a	5.14a	3.98a	3.74a
	15:2	2.93a	4.81a	2.73a	3.51a	3.68a	4.95a	3.68a	3.60a
	25:1	3.75d	5.88d	3.02b	3.75a	4.10a	6.12b	4.29a	4.38b
	25:2	3.65d	5.55j	2.93a	3.65a	3.97a	5.97b	3.94a	3.74a
Garlic	15:1	3.35c	6.29f	3.17b	4.03b	4.30a	6.53b	6.14c	4.82c
	15:2	3.30c	5.70c	3.02b	3.93b	4.13a	6.33b	5.78c	4.35b
	25:1	4.15f	7.27i	3.35c	4.15c	4.59a	7.75d	6.37c	5.37d
	25:2	4.06e	6.98h	3.30c	4.06b	4.48a	7.57d	6.15c	4.53b
Cumin	15:1	3.19b	6.50g	3.12b	4.13bc	6.13b	6.77c	6.54c	5.14c
	15:2	3.08ab	5.97e	2.99b	4.06b	6.05b	6.22b	6.24c	4.06ab
	25:1	4.35g	6.93h	3.19b	4.35c	6.36b	7.41d	6.79d	4.35b
	25:2	4.25f	6.48f	3.08b	4.25c	6.29b	7.08c	6.39c	4.25b
Fennel	15:1	3.27c	6.79h	3.19b	4.28c	6.90b	7.26d	4.87b	5.14c
	15:2	3.19b	5.83d	3.09b	4.21c	6.81b	6.58c	4.58a	4.91c
	25:1	4.42g	8.15lm	3.27b	4.42c	7.27b	8.09e	5.15b	5.38d
	25:2	4.34g	7.43i	3.19b	4.34c	7.13b	7.76d	7.34d	5.23c
Coriander	15:1	3.19b	8.69n	3.15b	3.91b	7.57b	8.07e	4.80b	4.60b
	15:2	3.14b	7.86k	3.06b	3.77a	7.47b	7.62d	4.60a	4.47b
	25:1	4.06e	7.95k	3.19b	4.06b	7.77b	8.51e	5.02b	4.81c
	25:2	3.92e	7.77k	3.14b	3.92b	7.68b	8.17e	4.75b	4.56b
Berseem	15:1	4.25f	8.25m	4.17d	5.88d	8.25c	8.67f	6.17c	6.31e
	15:2	4.21f	7.77k	4.05d	5.79d	8.06c	7.99e	5.93c	6.16e
	25:1	6.03l	9.75q	4.25e	6.03e	10.28d	10.42h	6.34c	6.42e
	25:2	5.87k	9.07o	4.21a	5.87d	10.10d	9.46g	6.10c	6.04e
Marigold	15:1	3.17b	6.02e	2.98 ab	4.18c	6.06b	6.54b	5.05b	5.12c
	15:2	3.08ab	5.93de	2.95a	4.12b	5.91b	6.29c	4.79b	4.93c
	25:1	4.32g	7.24i	3.17b	4.32c	6.93b	7.52d	5.38b	5.42d
	25:2	4.16f	6.79h	3.08b	4.16c	6.70b	7.08c	5.03b	5.26c
Cabbage		14.64m	13.17q	13.10g	12.71f	17.80e	19.92i	16.39e	18.41i
LSD (*P=0.05*)		0.15	0.207	0.247	0.31	1.90	0.59	0.970	0.46

Similar alphabets are non significant at 0.05 level by DMRT

A=60x45 cm row to row and plant to plant spacing

B=50x40 cm row to row and plant to plant spacing

15:1= 15 lines of cabbage and 1 line of intercrop

15:2= 15 lines of cabbage and 2 lines of intercrop

25:1= 25 lines of cabbage and 1 line of intercrop

25:2= 25 lines of cabbage and 2 lines of intercrop

Table-4.9b. Mean parasitoids population of *P. xylostella* during 2007-08 and 2008-09

Intercrop	Ratio	2007-08				2008-09			
		30-days old seedling		40-days old seedling		30-days old seedling		40-days old seedling	
		A	B	A	B	A	B	A	B
Radish	15:1	1.56k	1.20f	1.58i	1.25k	2.01d	1.98d	2.05d	2.03d
	15:2	1.54j	1.18e	1.55gh	1.20i	2.00d	1.95d	2.03d	2.02d
	25:1	1.15c	1.13d	1.18c	1.17gh	1.65b	1.63b	1.70b	1.67b
	25:2	1.12c	1.11d	1.15c	1.14e	1.63b	1.60b	1.67b	1.65b
Carrot	15:1	1.43h	1.25g	1.45f	1.26k	2.03d	2.00d	2.05d	2.04d
	15:2	1.45hi	1.22f	1.46f	1.25k	2.02d	2.02d	2.04d	2.03d
	25:1	1.05b	1.12d	1.25d	1.15ef	1.85c	1.83c	1.90c	1.86c
	25:2	1.05b	1.03b	1.20c	1.13e	1.62b	1.60b	1.70b	1.67b
Tomato	15:1	1.62l	1.54j	1.70j	1.64r	2.15f	2.11e	2.17e	2.15e
	15:2	1.59k	1.48i	1.63i	1.58p	2.05e	2.03d	2.13e	2.08d
	25:1	1.43h	1.39h	1.45f	1.40no	1.95d	1.90cd	2.07e	2.00d
	25:2	1.41h	1.36h	1.42f	1.38n	1.85c	1.83c	1.95d	1.90c
Garlic	15:1	1.58k	1.25g	1.60i	1.26k	2.15f	2.10e	2.16e	2.16e
	15:2	1.55jk	1.20f	1.58i	1.23j	2.10e	2.11e	2.15e	2.13e
	25:1	1.19d	1.18e	1.20c	1.20i	1.95d	1.90cd	1.98d	1.97d
	25:2	1.15c	1.20f	1.16c	1.22ij	1.79c	1.75bc	1.80c	1.79c
Cumin	15:1	1.55jk	1.26g	1.49g	1.28l	2.26g	2.20e	2.30f	2.25f
	15:2	1.54j	1.25g	1.50g	1.26k	2.23f	2.15e	2.25f	2.23ef
	25:1	1.32f	1.15de	1.27d	1.18h	2.20f	2.10e	2.22f	2.18e
	25:2	1.30f	1.05c	1.25d	1.15ef	2.10e	2.06e	2.15e	2.13e
Fennel	15:1	1.70m	1.60k	1.73k	1.66s	2.48i	2.45g	2.49h	2.47g
	15:2	1.63l	1.56j	1.65j	1.64r	2.30g	2.28f	2.33fg	2.30f
	25:1	1.25e	1.20f	1.27d	1.25k	2.30g	2.25f	2.32f	2.29f
	25:2	1.24de	1.18e	1.25d	1.23j	2.20f	2.23f	2.25f	2.24f
Coriander	15:1	1.65l	1.60k	1.69j	1.63qr	2.40h	2.38g	2.42g	2.39g
	15:2	1.50ij	1.48i	1.53g	1.61q	2.31g	2.30f	2.35g	2.33f
	25:1	1.25e	1.23f	1.27d	1.25k	2.45i	2.43g	2.48h	2.45g
	25:2	1.23d	1.20f	1.25d	1.22ij	2.43h	2.40g	2.45h	2.43g
Berseem	15:1	1.65l	1.50i	1.66j	1.62q	2.35gh	2.30f	2.40g	2.39g
	15:2	1.30f	1.20f	1.35e	1.29lm	2.23f	2.21ef	2.25f	2.23ef
	25:1	1.05b	1.03b	1.10b	1.09cd	2.20f	2.23f	2.25f	2.24f
	25:2	1.05b	1.02b	1.06b	1.04b	2.19f	2.20e	2.23f	2.21e
Marigold	15:1	1.50ij	1.26g	1.60i	1.27kl	2.36h	2.35f	2.38g	2.37g
	15:2	1.35fg	1.12d	1.52g	1.20i	2.28g	2.25f	2.30f	2.28f
	25:1	1.15c	1.12d	1.17c	1.15ef	2.13e	2.10e	2.15e	2.12e
	25:2	1.13c	1.00b	1.10b	1.07c	2.10e	2.08e	2.13e	2.10de
Cabbage		0.97a	0.95a	0.99a	1.01a	1.10a	1.03a	1.21a	1.16a
LSD (*P=0.05*)		0.05	0.04	0.06	0.02	0.09	0.15	0.11	0.13

Similar alphabets are non significant at 0.05 level by DMRT

A=60x45 cm row to row and plant to plant spacing

B=50x40 cm row to row and plant to plant spacing

15:1= 15 lines of cabbage and 1 line of intercrop

15:2= 15 lines of cabbage and 2 lines of intercrop

25:1= 25 lines of cabbage and 1 line of intercrop

25:2= 25 lines of cabbage and 2 lines of intercrop

Table-4.10. Percent parasitisation of *P. xylostella* during 2007-08 and 2008-09

Intercrop	Ratio	2007-08				2008-09			
		30-days old seedling		40-days old seedling		30-days old seedling		40-days old seedling	
		A	B	A	B	A	B	A	B
Radish	15:1	31.90	18.43	36.41	21.85	32.95	29.29	29.08	27.92
	15:2	32.56	21.18	36.73	21.43	37.04	29.50	31.23	29.45
	25:1	19.52	13.99	24.13	19.86	24.30	19.57	22.94	22.06
	25:2	19.51	14.07	24.31	19.86	25.47	19.61	24.38	22.88
Carrot	15:1	33.49	18.77	35.02	21.84	32.64	28.94	30.83	26.32
	15:2	34.69	22.10	36.59	22.16	33.55	30.98	33.55	27.25
	25:1	17.89	14.18	29.27	19.59	28.37	22.37	26.80	22.66
	25:2	18.42	13.64	28.71	19.82	25.35	19.88	25.80	22.39
Tomato	15:1	53.64	29.90	60.71	45.43	56.88	41.05	54.52	57.49
	15:2	54.27	30.77	59.71	45.01	55.71	41.01	57.88	57.78
	25:1	38.13	23.64	48.01	37.33	47.56	31.05	48.25	45.66
	25:2	38.63	24.50	48.46	37.81	46.60	30.65	49.49	50.80
Garlic	15:1	47.16	19.87	50.47	31.27	50.00	32.16	35.18	44.81
	15:2	46.97	21.05	52.32	31.30	50.85	33.33	37.20	48.97
	25:1	28.67	16.23	35.82	28.92	42.48	24.52	31.08	36.69
	25:2	28.33	17.19	35.15	30.05	39.96	23.12	29.27	39.51
Cumin	15:1	48.59	19.38	47.76	30.99	36.87	32.50	35.17	43.77
	15:2	50.00	20.94	50.17	31.03	36.86	34.57	36.06	54.93
	25:1	30.34	16.59	39.81	27.13	34.59	28.34	32.70	50.11
	25:2	30.59	16.20	40.58	27.06	33.39	29.10	33.65	50.12
Fennel	15:1	51.99	23.56	54.23	38.79	35.94	33.75	51.13	48.05
	15:2	51.10	26.76	53.40	38.95	33.77	34.65	50.87	46.84
	25:1	28.28	14.72	38.84	28.28	31.64	27.81	45.05	42.57
	25:2	28.57	15.88	39.18	28.34	30.86	28.74	30.65	42.83
Coriander	15:1	51.72	18.41	53.65	41.69	31.70	29.49	50.42	51.96
	15:2	47.77	18.83	50.00	42.71	30.92	30.18	51.09	52.13
	25:1	30.79	15.47	39.81	30.79	31.53	28.55	49.40	50.94
	25:2	31.38	15.44	39.81	31.12	31.64	29.38	51.58	53.29
Berseem	15:1	38.82	18.18	39.81	27.55	28.48	26.53	38.90	37.88
	15:2	30.88	15.44	33.33	22.28	27.67	27.66	37.94	36.20
	25:1	17.41	10.56	25.88	18.08	21.40	21.40	35.49	34.89
	25:2	17.89	11.25	25.18	17.72	21.68	23.26	36.56	36.59
Marigold	15:1	47.32	20.93	53.69	30.38	38.94	35.93	47.13	46.29
	15:2	43.83	18.89	51.53	29.13	38.58	35.77	48.02	46.25
	25:1	26.62	15.47	36.91	26.62	30.74	27.93	39.96	39.11
	25:2	27.16	14.73	35.71	25.72	31.34	29.38	42.35	39.92
	Cabbage	6.63	7.21	7.56	7.95	6.18	5.17	7.38	6.30

15:1= 15 lines of cabbage and 1 line of intercrop
15:2= 15 lines of cabbage and 2 lines of intercrop
25:1= 25 lines of cabbage and 1 line of intercrop
25:2= 25 lines of cabbage and 2 lines of intercrop

A=60x45 cm row to row and plant to plant spacing
B=50x40 cm row to row and plant to plant spacing

Table-4.11: Cost-benefit ratio of intercropping on the incidence of *P. xylostella* on cabbage (30-days old seedling of cabbage with spacing of 60x45 cm) in 2007-08

Intercrop	Ratio	Yield of cabbage (q/ha)	Increased yield over control (q/ha)	Increased return (Rs./ha)	Yield of intercrop (q/ha)	Return from intercrop (Rs./ha)	Additional return over sole crop (Rs./ha)
Radish	15:1	241.78e	38.51	19255.00	0.26	5200.00	24455.00
	15:2	243.10e	39.83	19915.00	0.42	8400.00	28315.00
	25:1	236.27d	33.00	16500.00	0.15	3000.00	19500.00
	25:2	237.53d	34.26	17130.00	0.25	5000.00	22130.00
Carrot	15:1	232.39d	29.12	14560.00	0.15	6000.00	20560.00
	15:2	234.12d	30.85	15425.00	0.22	8800.00	24225.00
	25:1	227.49c	24.22	12110.00	0.10	4000.00	16110.00
	25:2	228.64c	25.37	12685.00	0.13	5200.00	17885.00
Tomato	15:1	261.35g	58.08	29040.00	11.80	7080.00	36120.00
	15:2	264.61g	61.34	30670.00	17.00	10200.00	40870.00
	25:1	255.87f	52.60	26300.00	6.65	3990.00	30290.00
	25:2	256.15f	52.88	26440.00	10.35	6210.00	32650.00
Garlic	15:1	255.04f	51.77	25885.00	5.20	5200.00	31085.00
	15:2	255.76f	52.49	26245.00	7.90	7900.00	34145.00
	25:1	250.21f	46.94	23470.00	3.26	3260.00	26730.00
	25:2	250.65f	47.38	23690.00	4.75	4750.00	28440.00
Cumin	15:1	251.26f	47.99	23995.00	0.35	7700.00	31695.00
	15:2	253.32f	50.05	25025.00	0.50	11000.00	36025.00
	25:1	246.50e	43.23	21615.00	0.18	3960.00	25575.00
	25:2	247.14e	43.87	21935.00	0.27	5940.00	27875.00
Fennel	15:1	248.68f	45.41	22705.00	0.42	8400.00	31105.00
	15:2	250.05f	46.78	23390.00	0.60	12000.00	35390.00
	25:1	244.92e	41.65	20825.00	0.25	5000.00	25825.00
	25:2	245.45e	42.18	21090.00	0.38	7600.00	28690.00
Coriander	15:1	245.23e	41.96	20980.00	0.44	7920.00	28900.00
	15:2	245.78e	42.51	21255.00	0.65	11700.00	32955.00
	25:1	239.90d	36.63	18315.00	0.26	4680.00	22995.00
	25:2	240.35e	37.08	18540.00	0.40	7200.00	25740.00
Berseem	15:1	225.67c	22.4	11200.00	0.30	3000.00	14200.00
	15:2	226.33c	23.06	11530.00	0.36	3600.00	15130.00
	25:1	221.44c	18.17	9085.00	0.20	2000.00	11085.00
	25:2	221.79c	18.52	9260.00	0.28	2800.00	12060.00
Marigold	15:1	217.87b	14.60	7300.00	0.10	6500.00	13800.00
	15:2	218.27b	15.00	7500.00	0.14	9100.00	16600.00
	25:1	212.55b	9.28	4640.00	0.06	3900.00	8540.00
	25:2	212.89b	9.62	4810.00	0.11	7150.00	11960.00
Cabbage		203.27a	-	-	-	-	-
P=0.05		7.90					

Price of 1.cabbage @ Rs. 500/- q^{-1}, 2.Radish @ Rs. 20,000/- q^{-1}, 3.Carrot @ Rs. 40,000/- q^{-1}, 4.Tomato @ 600/- q^{-1}, 5.Garlic @ Rs. 1,000/- q^{-1} 6.Cumin @ 22,000/- q^{-1}, 7.Fennel @ 20,000/- q^{-1}, 8.Coriander @ 18,000/- q^{-1}, 9.Berseem @ 10,000/- q^{-1}, 10.Marigold @ 65,000/- q^{-1}

Table-4.12: Cost-benefit ratio of intercropping on the incidence of *P. xylostella* on cabbage (30- days old seedling of cabbage with spacing of 50x40 cm) in 2007-08

Intercrop	Ratio	Yield of cabbage (q/ha)	Increased yield over control (q/ha)	Increased return (Rs./ha)	Yield of intercrop (q/ha)	Return from intercrop (Rs./ha)	Additional return over sole crop (Rs./ha)
Radish	15:1	230.69d	34.91	17455.00	0.22	4400.00	21855.00
	15:2	231.05d	35.27	17635.00	0.39	7800.00	25435.00
	25:1	226.11c	30.33	15165.00	0.14	2800.00	17965.00
	25:2	226.79c	31.01	15505.00	0.23	4600.00	20105.00
Carrot	15:1	224.56c	28.78	14390.00	0.11	4400.00	18790.00
	15:2	225.19c	29.41	14705.00	0.19	7600.00	22305.00
	25:1	219.27c	23.49	11745.00	0.07	2800.00	14545.00
	25:2	219.98c	24.10	12050.00	0.11	4400.00	16450.00
Tomato	15:1	252.83f	57.05	28525.00	11.25	6750.00	35275.00
	15:2	253.16f	57.38	28690.00	16.50	9900.00	38590.00
	25:1	247.58e	51.80	25900.00	6.30	3780.00	29680.00
	25:2	248.03f	52.25	26125.00	10.05	6030.00	32155.00
Garlic	15:1	245.11e	49.33	24665.00	5.00	5000.00	29665.00
	15:2	245.76e	49.98	24990.00	7.75	7750.00	32740.00
	25:1	240.37e	44.59	22295.00	3.04	3040.00	25335.00
	25:2	240.93e	45.15	22575.00	4.48	4480.00	27055.00
Cumin	15:1	240.53e	44.75	22375.00	0.32	7040.00	29415.00
	15:2	241.08e	45.30	22650.00	0.45	9900.00	32550.00
	25:1	236.27d	40.49	20245.00	0.16	3520.00	23765.00
	25:2	236.79d	41.01	20505.00	0.24	5280.00	25785.00
Fennel	15:1	237.65d	41.87	20935.00	0.33	6600.00	27535.00
	15:2	238.43e	42.65	21325.00	0.46	9200.00	30525.00
	25:1	233.18d	37.40	18700.00	0.22	4400.00	23100.00
	25:2	233.84d	38.06	19030.00	0.33	6600.00	25630.00
Coriander	15:1	234.47d	38.69	19345.00	0.38	6840.00	26185.00
	15:2	234.96d	39.18	19590.00	0.58	10440.00	30030.00
	25:1	228.85d	33.07	16535.00	0.21	3780.00	20315.00
	25:2	229.24d	33.46	16730.00	0.34	6120.00	22850.00
Berseem	15:1	214.37b	18.59	9295.00	0.27	2700.00	11995.00
	15:2	214.79b	19.01	9505.00	0.31	3100.00	12605.00
	25:1	210.29b	14.51	7255.00	0.16	1600.00	8855.00
	25:2	211.13b	15.35	7675.00	0.21	2100.00	9775.00
Marigold	15:1	208.53b	12.75	6375.00	0.09	5850.00	12225.00
	15:2	209.25b	13.47	6735.00	0.12	7800.00	14535.00
	25:1	204.07a	8.29	4145.00	0.05	3250.00	7395.00
	25:2	204.80a	9.02	4510.00	0.10	6500.00	11010.00
Cabbage		195.78a	-	-	-	-	-
P=0.05		9.33					

Table-4.13: Cost-benefit ratio of intercropping on the incidence of *P. xylostella* on cabbage (40- days old seedling of cabbage with spacing of 60x45 cm) in 2007-08

Intercrop	Ratio	Yield of cabbage (q/ha)	Increased yield over control (q/ha)	Increased return (Rs./ha)	Yield of intercrop (q/ha)	Return from intercrop (Rs./ha)	Additional return over sole crop (Rs./ha)
Radish	15:1	242.82d	37.61	18805.00	0.27	5400.00	24205.00
	15:2	244.05d	38.84	19420.00	0.43	8600.00	28020.00
	25:1	239.55d	34.34	17170.00	0.18	3600.00	20770.00
	25:2	240.30d	35.09	17545.00	0.25	5000.00	22545.00
Carrot	15:1	234.23c	29.02	14510.00	0.14	5600.00	20110.00
	15:2	234.63c	29.42	14710.00	0.24	9600.00	24310.00
	25:1	228.85c	23.64	11820.00	0.11	4400.00	16220.00
	25:2	229.13c	23.92	11960.00	0.13	5200.00	17160.00
Tomato	15:1	263.42f	58.21	29105.00	12.00	7200.00	36305.00
	15:2	265.70f	60.49	30245.00	17.22	10332.00	40577.00
	25:1	258.27e	53.06	26530.00	6.70	4020.00	30550.00
	25:2	258.77e	53.56	26780.00	10.42	6252.00	33032.00
Garlic	15:1	256.47e	51.26	25630.00	5.23	5230.00	30860.00
	15:2	256.95e	51.74	25870.00	7.92	7920.00	33790.00
	25:1	253.38e	48.17	24085.00	3.25	3250.00	27335.00
	25:2	253.69e	48.48	24240.00	4.77	4770.00	29010.00
Cumin	15:1	252.88e	47.67	23835.00	0.36	7920.00	31755.00
	15:2	254.67e	49.46	24730.00	0.52	11440.00	36170.00
	25:1	247.89d	42.68	21340.00	0.20	4400.00	25740.00
	25:2	248.35d	43.14	21570.00	0.28	6160.00	27730.00
Fennel	15:1	249.92e	44.71	22355.00	0.43	8600.00	30955.00
	15:2	251.29e	46.08	23040.00	0.61	12200.00	35240.00
	25:1	246.16d	40.95	20475.00	0.26	5200.00	25675.00
	25:2	246.52d	41.31	20655.00	0.38	7600.00	28255.00
Coriander	15:1	246.55d	41.34	20670.00	0.45	8100.00	28770.00
	15:2	247.02d	41.81	20905.00	0.65	11700.00	32605.00
	25:1	241.11d	35.90	17950.00	0.25	4500.00	22450.00
	25:2	241.49d	36.28	18140.00	0.42	7560.00	25700.00
Berseem	15:1	225.86b	20.65	10325.00	0.32	3200.00	13525.00
	15:2	226.41c	21.20	10600.00	0.35	3500.00	14100.00
	25:1	222.08b	16.87	8435.00	0.21	2100.00	10535.00
	25:2	222.30b	17.09	8545.00	0.30	3000.00	11545.00
Marigold	15:1	218.20b	12.99	6495.00	0.11	7150.00	13645.00
	15:2	218.35b	13.14	6570.00	0.15	9750.00	16320.00
	25:1	215.26a	10.05	5025.00	0.08	5200.00	10225.00
	25:2	216.11b	10.90	5450.00	0.10	6500.00	11950.00
Cabbage		205.21a	-	-	-	-	-
P=0.05		10.12					

Table-4.14: Cost-benefit ratio of intercropping on the incidence of *P. xylostella* on cabbage (40-days old seedling of cabbage with spacing of 50x40 cm) in 2007-08

Intercrop	Ratio	Yield of cabbage (q/ha)	Increased yield over control (q/ha)	Increased return (Rs./ha)	Yield of intercrop (q/ha)	Return from intercrop (Rs./ha)	Additional return over sole crop (Rs./ha)
Radish	15:1	232.11c	31.06	15530.00	0.25	5000.00	20530.00
	15:2	234.13c	33.08	16540.00	0.40	8000.00	24540.00
	25:1	229.38c	28.33	14165.00	0.17	3400.00	17565.00
	25:2	230.26c	29.21	14605.00	0.23	4600.00	19205.00
Carrot	15:1	225.67c	24.62	12310.00	0.12	4800.00	17110.00
	15:2	226.07c	25.02	12510.00	0.22	8800.00	21310.00
	25:1	220.12b	19.07	9535.00	0.10	4000.00	13535.00
	25:2	220.58b	19.53	9765.00	0.11	4400.00	14165.00
Tomato	15:1	250.53e	49.48	24740.00	11.50	6900.00	31640.00
	15:2	253.85e	52.80	26400.00	17.00	10200.00	36600.00
	25:1	248.22e	47.17	23585.00	6.20	3720.00	27305.00
	25:2	248.97e	47.92	23960.00	10.12	6072.00	30032.00
Garlic	15:1	246.33e	45.28	22640.00	5.15	5150.00	27790.00
	15:2	246.80e	45.75	22875.00	7.60	7600.00	30475.00
	25:1	244.67d	43.62	21810.00	3.11	3110.00	24920.00
	25:2	244.90d	43.85	21925.00	4.50	4500.00	26425.00
Cumin	15:1	241.21d	40.16	20080.00	0.33	7260.00	27340.00
	15:2	242.37d	41.32	20660.00	0.50	11000.00	31660.00
	25:1	237.76d	36.71	18355.00	0.19	4180.00	22535.00
	25:2	238.05d	37.00	18500.00	0.26	5720.00	24220.00
Fennel	15:1	238.40d	37.35	18675.00	0.42	8400.00	27075.00
	15:2	240.10d	39.05	19525.00	0.60	12000.00	31525.00
	25:1	235.27d	34.22	17110.00	0.25	5000.00	22110.00
	25:2	235.56d	34.51	17255.00	0.36	7200.00	24455.00
Coriander	15:1	235.60d	34.55	17275.00	0.44	7920.00	25195.00
	15:2	236.00d	34.95	17475.00	0.63	11340.00	28815.00
	25:1	229.77c	28.71	14355.00	0.24	4320.00	18675.00
	25:2	230.17c	29.12	14560.00	0.40	7200.00	21760.00
Berseem	15:1	217.43b	16.38	8190.00	0.30	3000.00	11190.00
	15:2	217.78b	16.73	8365.00	0.33	3300.00	11665.00
	25:1	214.31b	13.26	6630.00	0.20	2000.00	8630.00
	25:2	214.50b	13.45	6725.00	0.28	2800.00	9525.00
Marigold	15:1	210.47a	9.42	4710.00	0.10	6500.00	11210.00
	15:2	210.60a	9.55	4775.00	0.14	9100.00	13875.00
	25:1	207.35a	6.30	3150.00	0.07	4550.00	7700.00
	25:2	208.06a	7.01	3505.00	0.09	5850.00	9355.00
Cabbage		201.05a	-	-	-	-	-
P=0.05		9.57					

Table-4.15: Cost-benefit ratio of intercropping on the incidence of *P. xylostella* on cabbage (30-days old seedling of cabbage with spacing of 60x45 cm) in 2008-09

Intercrop	Ratio	Yield of cabbage (q/ha)	Increased yield over control (q/ha)	Increased return (Rs./ha)	Yield of intercrop (q/ha)	Return from intercrop (Rs./ha)	Additional return over sole crop (Rs./ha)
Radish	15:1	237.35d	37.23	22338.00	0.26	5100.00	27438.00
	15:2	238.52d	38.40	23040.00	0.40	8000.00	31040.00
	25:1	232.15c	32.03	19218.00	0.15	2900.00	22118.00
	25:2	232.68c	32.56	19536.00	0.25	4900.00	24436.00
Carrot	15:1	228.43c	28.31	16986.00	0.15	5840.00	22826.00
	15:2	229.24c	29.12	17472.00	0.20	8000.00	25472.00
	25:1	223.18c	23.06	13836.00	0.09	3680.00	17516.00
	25:2	223.62c	23.50	14100.00	0.12	4920.00	19020.00
Tomato	15:1	259.28f	59.16	35496.00	11.50	6900.00	42396.00
	15:2	260.39f	60.27	36162.00	15.90	9540.00	45702.00
	25:1	253.40e	53.28	31968.00	6.30	3780.00	35748.00
	25:2	253.77e	53.65	32190.00	10.00	6000.00	38190.00
Garlic	15:1	252.30e	52.18	31308.00	4.85	4850.00	36158.00
	15:2	253.08e	52.96	31776.00	7.45	7450.00	39226.00
	25:1	248.47e	48.35	29010.00	3.12	3120.00	32130.00
	25:2	249.11e	48.99	29394.00	4.40	4400.00	33794.00
Cumin	15:1	247.50e	47.38	28428.00	0.34	7480.00	35908.00
	15:2	249.13e	49.01	29406.00	0.45	9900.00	39306.00
	25:1	235.14d	35.02	21012.00	0.17	3740.00	24752.00
	25:2	235.68d	35.56	21336.00	0.27	5830.00	27166.00
Fennel	15:1	243.90d	43.78	26268.00	0.41	8200.00	34468.00
	15:2	246.27e	46.15	27690.00	0.58	11600.00	39290.00
	25:1	239.65d	39.53	23718.00	0.24	4800.00	28518.00
	25:2	240.17d	40.05	24030.00	0.35	7000.00	31030.00
Coriander	15:1	239.76d	39.64	23784.00	0.42	7560.00	31344.00
	15:2	240.12d	40.00	24000.00	0.62	11160.00	35160.00
	25:1	235.26d	35.14	21084.00	0.25	4500.00	25584.00
	25:2	235.83d	35.71	21426.00	0.38	6840.00	28266.00
Berseem	15:1	219.85b	19.73	11838.00	0.28	2800.00	14638.00
	15:2	220.37b	20.25	12150.00	0.35	3500.00	15650.00
	25:1	215.68b	15.56	9336.00	0.18	1800.00	11136.00
	25:2	216.05b	15.93	9558.00	0.25	2500.00	12058.00
Marigold	15:1	213.62b	13.50	8100.00	0.09	5525.00	13625.00
	15:2	214.19b	14.07	8442.00	0.14	8775.00	17217.00
	25:1	207.76a	7.64	4584.00	0.05	3250.00	7834.00
	25:2	208.20a	8.08	4848.00	0.10	6500.00	11348.00
Cabbage		200.12a	-	-	-	-	-
P=0.05		9.53					

Price of 1.cabbage @ Rs. 600/- q^{-1}, 2.Radish @ Rs. 20,000/- q^{-1},
3.Carrot @ Rs. 40,000/- q^{-1}, 4.Tomato @ 600/- q^{-1}, 5.Garlic @ Rs. 1,000/- q^{-1}
6.Cumin @ 22,000/- q^{-1}, 7.Fennel @ 20,000/- q^{-1}, 8.Coriander @ 18,000/- q^{-1},
9.Berseem @ 10,000/- q-1, 10.Marigold @ 62,000/- q^{-1}

Table-4.16: Cost-benefit ratio of intercropping on the incidence of *P. xylostella* on cabbage (30-days old seedling of cabbage with spacing of 50x40 cm) in 2008-09

Intercrop	Ratio	Yield of cabbage (q/ha)	Increased yield over control (q/ha)	Increased return (Rs./ha)	Yield of intercrop (q/ha)	Return from intercrop (Rs./ha)	Additional return over sole crop (Rs./ha)
Radish	15:1	226.75c	34.89	20934.00	0.21	4240.00	25174.00
	15:2	227.23c	35.37	21222.00	0.37	7400.00	28622.00
	25:1	222.87c	31.01	18606.00	0.13	2660.00	21266.00
	25:2	223.28c	31.42	18852.00	0.21	4200.00	23052.00
Carrot	15:1	221.32c	29.46	17676.00	0.10	4080.00	21756.00
	15:2	221.80c	29.94	17964.00	0.18	7200.00	25164.00
	25:1	215.90b	24.04	14424.00	0.06	2560.00	16984.00
	25:2	216.42c	24.56	14736.00	0.10	4000.00	18736.00
Tomato	15:1	248.65e	56.79	34074.00	10.90	6540.00	40614.00
	15:2	249.08e	57.22	34332.00	15.75	9450.00	43782.00
	25:1	244.35e	52.49	31494.00	5.92	3552.00	35046.00
	25:2	245.27e	53.41	32046.00	9.72	5832.00	37878.00
Garlic	15:1	242.39e	50.53	30318.00	4.80	4800.00	35118.00
	15:2	242.87e	51.01	30606.00	7.50	7500.00	38106.00
	25:1	236.56d	44.70	26820.00	2.88	2880.00	29700.00
	25:2	236.82d	44.96	26976.00	4.30	4300.00	31276.00
Cumin	15:1	237.55d	45.69	27414.00	0.31	6886.00	34300.00
	15:2	238.05d	46.19	27714.00	0.45	9790.00	37504.00
	25:1	232.78d	40.92	24552.00	0.15	3388.00	27940.00
	25:2	233.10d	41.24	24744.00	0.23	5104.00	29848.00
Fennel	15:1	234.15d	42.29	25374.00	0.32	6440.00	31814.00
	15:2	234.70d	42.84	25704.00	0.45	9000.00	34704.00
	25:1	230.16d	38.30	22980.00	0.21	4280.00	27260.00
	25:2	230.67d	38.81	23286.00	0.32	6400.00	29686.00
Coriander	15:1	230.55d	38.69	23214.00	0.36	6480.00	29694.00
	15:2	231.18d	39.32	23592.00	0.55	9900.00	33492.00
	25:1	225.28c	33.42	20052.00	0.21	3852.00	23904.00
	25:2	225.94c	34.08	20448.00	0.32	5814.00	26262.00
Berseem	15:1	211.34b	19.48	11688.00	0.26	2600.00	14288.00
	15:2	211.86b	20.00	12000.00	0.30	3000.00	15000.00
	25:1	206.69b	14.83	8898.00	0.15	1520.00	10418.00
	25:2	207.24b	15.38	9228.00	0.20	2030.00	11258.00
Marigold	15:1	205.18b	13.32	7992.00	0.09	5580.00	13572.00
	15:2	205.69b	13.83	8298.00	0.12	7440.00	15738.00
	25:1	201.58a	9.72	5832.00	0.05	3100.00	8932.00
	25:2	202.27a	10.41	6246.00	0.09	5580.00	11826.00
Cabbage		191.86a	-	-	-	-	-
P=0.05		10.91					

Table-4.17: Cost-benefit ratio of intercropping on the incidence of *P. xylostella* on cabbage (40-days old seedling of cabbage with spacing of 60x45 cm) in 2008-09

Intercrop	Ratio	Yield of cabbage (q/ha)	Increased yield over control (q/ha)	Increased return (Rs./ha)	Yield of intercrop (q/ha)	Return from intercrop (Rs./ha)	Additional return over sole crop (Rs./ha)
Radish	15:1	238.65d	37.33	22398.00	0.26	5240.00	27638.00
	15:2	239.33d	38.01	22806.00	0.42	8400.00	31206.00
	25:1	235.30d	33.98	20388.00	0.17	3480.00	23868.00
	25:2	235.91d	34.59	20754.00	0.24	4860.00	25614.00
Carrot	15:1	231.36c	30.04	18024.00	0.14	5440.00	23464.00
	15:2	231.78c	30.46	18276.00	0.23	9320.00	27596.00
	25:1	225.26c	23.94	14364.00	0.11	4200.00	18564.00
	25:2	225.82c	24.50	14700.00	0.12	4920.00	19620.00
Tomato	15:1	260.51f	59.19	35514.00	11.20	6720.00	42234.00
	15:2	261.84f	60.52	36312.00	16.88	10128.00	46440.00
	25:1	254.75e	53.43	32058.00	6.45	3870.00	35928.00
	25:2	255.34f	54.02	32412.00	9.95	5970.00	38382.00
Garlic	15:1	253.54e	52.22	31332.00	5.08	5080.00	36412.00
	15:2	254.21e	52.89	31734.00	7.36	7360.00	39094.00
	25:1	250.08e	48.76	29256.00	3.02	3020.00	32276.00
	25:2	250.47e	49.15	29490.00	4.39	4390.00	33880.00
Cumin	15:1	248.25e	46.93	28158.00	0.35	7700.00	35858.00
	15:2	249.13e	47.81	28686.00	0.50	11000.00	39686.00
	25:1	243.24d	41.92	25152.00	0.19	4224.00	29376.00
	25:2	243.68d	42.36	25416.00	0.27	5940.00	31356.00
Fennel	15:1	245.36e	44.04	26424.00	0.42	8400.00	34824.00
	15:2	246.72e	45.40	27240.00	0.59	11800.00	39040.00
	25:1	242.12d	40.80	24480.00	0.25	5040.00	29520.00
	25:2	242.67d	41.35	24810.00	0.37	7400.00	32210.00
Coriander	15:1	241.76d	40.44	24264.00	0.44	7920.00	32184.00
	15:2	242.27d	40.95	24570.00	0.63	11340.00	35910.00
	25:1	236.93d	35.61	21366.00	0.24	4392.00	25758.00
	25:2	237.33d	36.01	21606.00	0.41	7380.00	28986.00
Berseem	15:1	222.32c	21.00	12600.00	0.31	3120.00	15720.00
	15:2	223.14c	21.82	13092.00	0.34	3400.00	16492.00
	25:1	219.21b	17.89	10734.00	0.20	2040.00	12774.00
	25:2	219.56b	18.24	10944.00	0.29	2900.00	13844.00
Marigold	15:1	215.42b	14.10	8460.00	0.11	6825.00	15285.00
	15:2	215.76b	14.44	8664.00	0.14	9295.00	17959.00
	25:1	211.64b	10.32	6192.00	0.07	4550.00	10742.00
	25:2	212.08b	10.76	6456.00	0.09	5850.00	12306.00
Cabbage		201.32a	-	-	-	-	-
P=0.05		9.64					

Table-4.18: Cost-benefit ratio of intercropping on the incidence of *P. xylostella* on cabbage (40-days old seedling of cabbage with spacing of 50x40 cm) in 2008-09

Intercrop	Ratio	Yield of cabbage (q/ha)	Increased yield over control (q/ha)	Increased return (Rs./ha)	Yield of intercrop (q/ha)	Return from intercrop (Rs./ha)	Additional return over sole crop (Rs./ha)
Radish	15:1	228.64d	33.24	19944.00	0.25	4900.00	24844.00
	15:2	229.27d	33.87	20322.00	0.38	7680.00	28002.00
	25:1	225.44d	30.04	18024.00	0.17	3360.00	21384.00
	25:2	226.06d	30.66	18396.00	0.23	4520.00	22916.00
Carrot	15:1	223.06d	27.66	16596.00	0.12	4640.00	21236.00
	15:2	223.79d	28.39	17034.00	0.22	8600.00	25634.00
	25:1	216.15c	20.75	12450.00	0.10	3840.00	16290.00
	25:2	216.65c	21.25	12750.00	0.10	4000.00	16750.00
Tomato	15:1	249.75g	54.35	32610.00	11.23	6738.00	39348.00
	15:2	250.67g	55.27	33162.00	16.70	10020.00	43182.00
	25:1	246.55g	51.15	30690.00	5.95	3570.00	34260.00
	25:2	247.04g	51.64	30984.00	10.02	6012.00	36996.00
Garlic	15:1	243.18f	47.78	28668.00	5.08	5080.00	33748.00
	15:2	243.65f	48.25	28950.00	7.45	7450.00	36400.00
	25:1	240.96f	45.56	27336.00	3.06	3060.00	30396.00
	25:2	241.48f	46.08	27648.00	4.19	4190.00	31838.00
Cumin	15:1	238.90e	43.50	26100.00	0.32	7128.00	33228.00
	15:2	239.29f	43.89	26334.00	0.49	10780.00	37114.00
	25:1	233.23e	37.83	22698.00	0.19	4092.00	26790.00
	25:2	233.79e	38.39	23034.00	0.25	5588.00	28622.00
Fennel	15:1	235.42e	40.02	24012.00	0.41	8200.00	32212.00
	15:2	236.75e	41.35	24810.00	0.59	11700.00	36510.00
	25:1	232.13e	36.73	22038.00	0.25	4920.00	26958.00
	25:2	232.87e	37.47	22482.00	0.35	7000.00	29482.00
Coriander	15:1	231.87e	36.47	21882.00	0.43	7740.00	29622.00
	15:2	232.29e	36.89	22134.00	0.61	10980.00	33114.00
	25:1	226.55d	31.15	18690.00	0.24	4230.00	22920.00
	25:2	227.02d	31.62	18972.00	0.39	7020.00	25992.00
Berseem	15:1	214.63c	19.23	11538.00	0.29	2940.00	14478.00
	15:2	214.97c	19.57	11742.00	0.32	3220.00	14962.00
	25:1	210.80b	15.40	9240.00	0.20	1950.00	11190.00
	25:2	211.18b	15.78	9468.00	0.25	2500.00	11968.00
Marigold	15:1	206.35b	10.95	6570.00	0.10	6240.00	12810.00
	15:2	206.74b	11.34	6804.00	0.13	8515.00	15319.00
	25:1	204.17b	8.77	5262.00	0.06	3900.00	9162.00
	25:2	204.69b	9.29	5574.00	0.07	4550.00	10124.00
Cabbage		195.40a	-	-	-	-	-
P=0.05		7.21					

Table-4.19. Correlation between weather parameters and average population of *P. xylostella* (2007-08)

Parameter	30-days old seedling of cabbage								40-days old seedling of cabbage							
	15:1		15:2		25:1		25:2		15:1		15:2		25:1		25:2	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Max.Temp.	0.09	0.08	-0.62	0.07	-0.52	-0.31	-0.51	-0.30	-0.54	-0.6	-0.53	-0.58	-0.72*	-0.60	-0.71*	-0.57
Min.Temp.	0.1	0.06	-0.53	0.04	-0.50	-0.29	-0.49	-0.30	-0.45	-0.57	-0.44	-0.55	-0.60	-0.58	-0.59	-0.55
Avg.Hum.	-0.22	-0.22	-0.11	-0.21	-0.19	-0.24	-0.19	-0.24	-0.13	-0.18	-0.14	-0.19	-0.07	-0.19	-0.08	-0.19
Rainfall (mm.)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table-4.20. Correlation between weather parameters and average population of *P. xylostella* (2008-09)

Parameter	30-days old seedling of cabbage								40-days old seedling of cabbage							
	15:1		15:2		25:1		25:2		15:1		15:2		25:1		25:2	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Max.Temp.	0.28	0.35	0.28	0.35	0.23	0.21	0.24	0.20	0.43	0.21	0.43	0.20	0.43	0.18	0.43	0.20
Min.Temp.	0.16	0.23	0.16	0.22	0.11	0.09	0.12	0.09	0.31	0.08	0.30	0.07	0.30	0.06	0.31	0.08
Avg.Hum.	-0.19	-0.26	-0.18	-0.26	-0.13	-0.11	-0.14	-0.11	-0.36	-0.12	-0.35	-0.11	-0.35	-0.08	-0.35	-0.10
Rainfall (mm.)	0.52	0.52	0.53	0.54	0.48	0.47	0.48	0.49	0.50	0.55	0.51	0.55	0.52	0.56	0.52	0.54

Table-4.21. Correlation between weather parameters and average parasitoid population of *P. xylostella* (2007-08)

Parameter	30-days old seedling of cabbage								40-days old seedling of cabbage							
	15:1		15:2		25:1		25:2		15:1		15:2		25:1		25:2	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Max.Temp.	-0.34	-0.17	-0.80**	-0.52	-0.5	-0.35	-0.49	-0.43	0.02	-0.15	-0.39	-0.38	-0.45	-0.38	-0.56	-0.51
Min.Temp.	-0.33	-0.32	-0.72*	-0.64	-0.61	-0.50	-0.63	-0.49	-0.04	-0.31	-0.33	-0.53	-0.63	-0.52	-0.72*	-0.59
Avg.Hum.	0.16	-0.29	0.31	-0.16	-0.13	-0.08	-0.21	0.15	0.20	-0.29	0.43	-0.20	-0.33	-0.07	-0.31	0.02
Rainfall (mm.)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table-4.22. Correlation between weather parameters and average parasitoid population of *P. xylostella* (2008-09)

Parameter	30-days old seedling of cabbage								40-days old seedling of cabbage							
	15:1		15:2		25:1		25:2		15:1		15:2		25:1		25:2	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Max.Temp.	0.53	0.55	0.61	0.58	0.34	0.40	0.44	0.45	0.56	0.58	0.51	0.57	0.27	0.31	0.40	0.41
Min.Temp.	0.39	0.41	0.48	0.43	0.19	0.25	0.33	0.33	0.42	0.44	0.39	0.45	0.12	0.16	0.27	0.29
Avg.Hum.	-0.44	-0.47	-0.52	-0.49	-0.26	-0.32	-0.36	-0.37	-0.48	-0.50	-0.42	-0.47	-0.19	-0.24	-0.32	-0.33
Rainfall (mm.)	0.35	0.38	0.42	0.47	0.57	0.59	0.59	0.56	0.34	0.32	0.46	0.47	0.57	0.57	0.57	0.57

A=60x45 cm row to row and plant to plant spacing

B=50x40 cm row to row and plant to plant spacing

* Significant correlation at 0.05 level

* *Significant correlation at 0.01 level

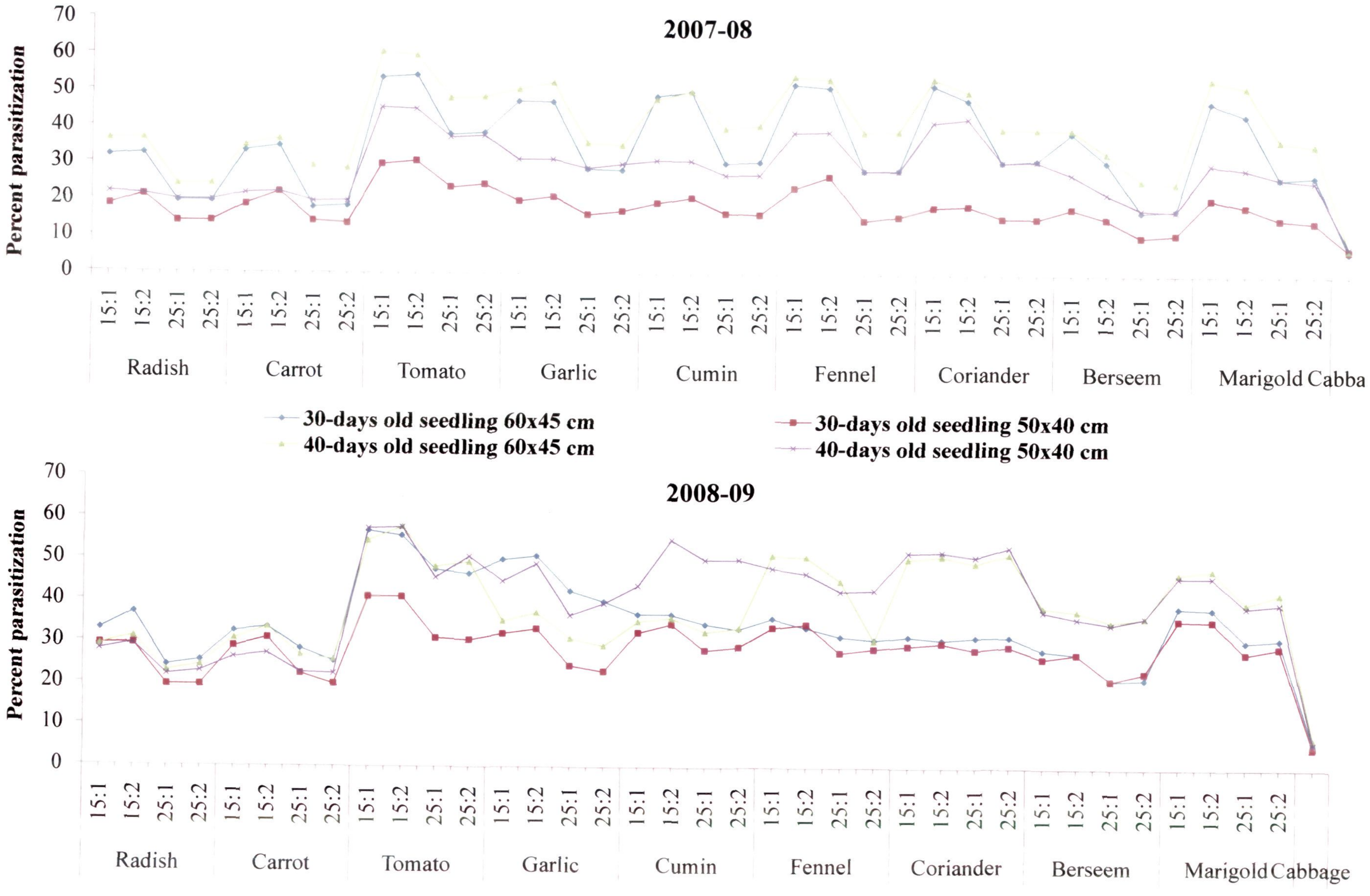


Fig.4: Percent parasitization of *P. xylostella* in intercropping system

Plate 1. Intercropping .
A. Cabbage + Coriander (15:2)
B. Cabbage + Coriander (25:1)

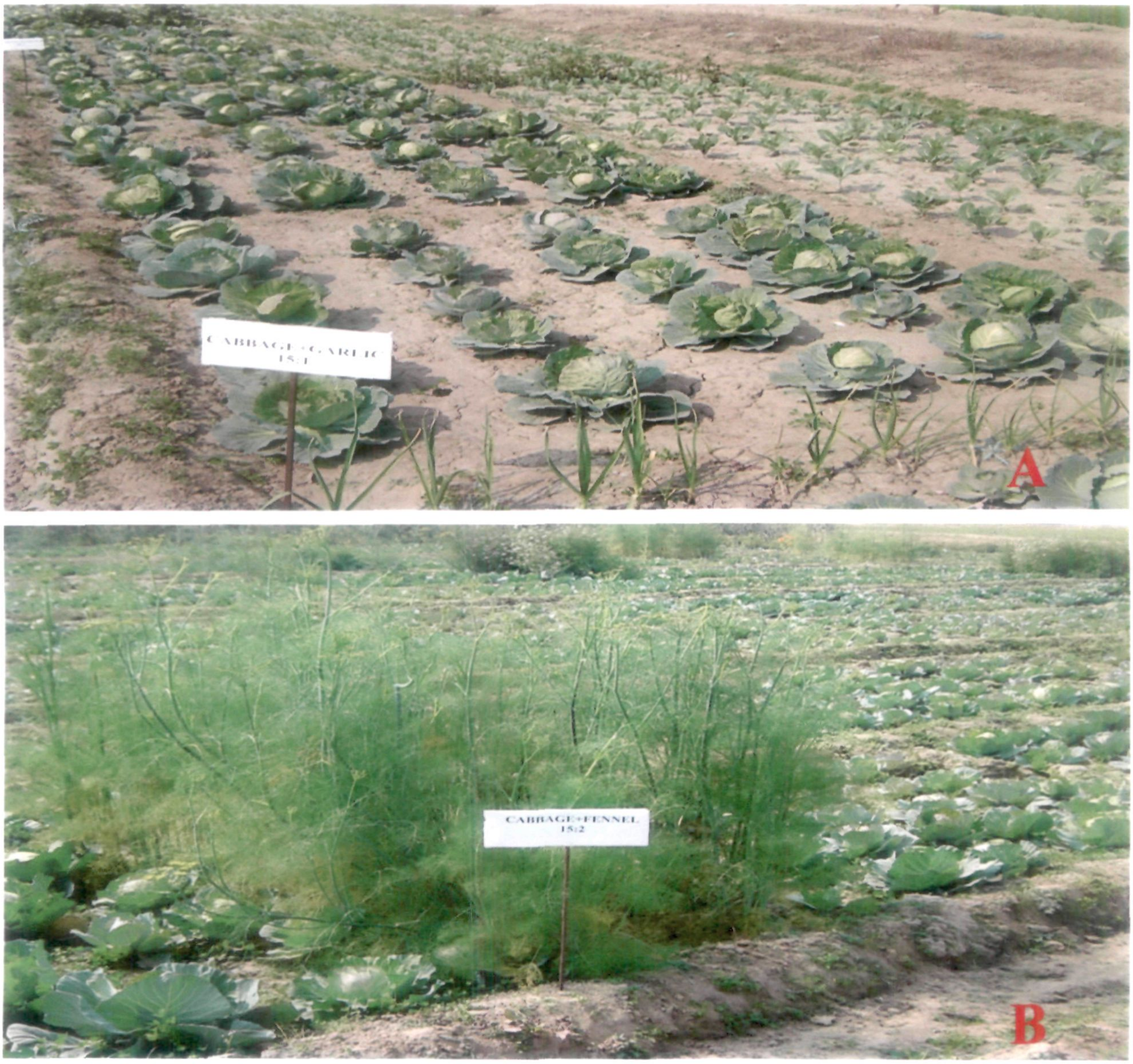


Plate 2. Intercropping .
A. Cabbage + Garlic (15:1)
B. Cabbage + Fennel (15:2)

Plate 3. Intercropping .
A. Cabbage + Tomato (15:2)
B. Cabbage + Marigold (15:2)

b. Effect of biopesticides against *P. xylostella* on cabbage:

Analyzed results (Table. 5.1-5.2, Plate. 4, 5, 6, A, B, C) showed that biopesticides offered a significant (P<0.05) reduction in larvae and pupae of *P. xylostella* at 1, 3, 7 and 10 days after treatment over control. Neem azal 0.50% EC was significantly (P<0.05) the best treatment followed by neem excel 0.15% EC and cartap hydrochloride 50 SP against *P. xylostella* in all the spraying schedules during both years of 2007-08 and 2008-09. Application of neem azal @ 0.25, 0.50 and 1.00% at 30, 50 and 70 days after transplantation (DAT) was found most effective registering 40.0-63.62%, 60.13-77.02% and 75.24-89.45% reduction in the population of *P. xylostella* as compared to control in 2007-08. Whereas, 41.79-65.36%, 60.46-76.97%, and 75.16-91.86% reduction was obtained in larval population over control in three round sprays, respectively in 2008-09. Neem azal and neem excel were similar in efficacy during both years of study. Application of neem excel @ 0.25, 0.50 and 1.00% at 30, 50 and 70 DAT gave 36.55-62.17%, 59.28-76.58% and 73.88-87.02% reduction in 2007-08. While 39.68-67.00%, 58.35-74.89% and 74.76-89.94% reduction was found in larval and pupal population over control in 2008-09. However, cartap hydrochloride gave 35.25-61.71%, 54.55-76.41% and 71.35-82.76% reduction in 2007-08 (Table-5.1). While, 38.55-65.54, 56.24-73.85 and 71.41-84.63% reduction in population as compared to control in three round sprays, respectively in 2008-09 (Table-5.2). Reduction in larvae and pupae population was also recorded in NSKE which ranged between 22.22-32.04%, 19.80-44.96% and 51.39-40.02%, respectively in 2007-08 and 21.78-37.50%, 24.27-38.59%, and 41.14-51.86%, respectively in 2008-09. Multineem and neemarin were statistically same at 1 and 10 days after spraying. While, they were significantly (P<0.05) differed at 3 and 7 days after I round. However, they were significantly differed at 3, 7 and 10 days after in II and III round in 2007-08 and 2008-09. Ultineem and NSKE were significantly (P<0.05) differed in both years except 1 DAS, which was recorded at par in 2007-08. Efficacy of neemarin and ultineem were also same at 3 and 7 days after treatment but significantly differed at 1 and 10 days after I round and 7 and 10 days after II round in 2007-08. Cartap hydrochloride and dichlorvos were equally effective at 1 and 3, but significantly differed at 7 and 10 days after I round as well as 3, 7 and 10 days after II round spray. While, significantly differed at 1, 3, 7 and 10 days after III round in 2007-08. However, substantial difference was obtained in 2008-09.

Yield performance and cost benefit ratio (Table-5.3, 5.4) revealed that all the treatments produced significantly ($P<0.05$) higher marketable yield of cabbage as compared to control during both years of study. Maximum yield was produced in neem azal i.e. 281.73 and 275.62 qha^{-1} in 2007-08 and 2008-09, respectively followed by neem excel cartap hydrochloride and multineem. Lowest yield i.e. 212.43 and 207.60 qha^{-1} of cabbage was recorded in control plot in 2007-08 and 2008-09, respectively. Yield of cabbage in ultineem and NSKE were statistically similar. Yield from neemarin and dichlorvos was also same statistically in both years of study. The yield of cabbage produced during I year was higher than that of II year in their respective treatments. It may be due to low pest infestation and favourable environmental condition in 2007-08 as compared to 2008-09.

Neem azal exhibited the highest benefit cost ratio (13.55:1) followed by multineem (12.51:1), dichlorvos (12.21:1) and cartap hydrochloride (11.38:1) in 2007-08. Whereas, substantially highest benefit cost ratio i.e. 14.02:1 was obtained in neem azal followed by dichlorvos (12.87:1), multineem (12.76:1) and cartap hydrochloride (12.12:1). Neemarin showed the lowest benefit cost ratio i.e. 7.81:1and 7.61:1in 2007-08 and 2008-09, respectively. Although, NSKE exhibited considerably better benefit cost ratio i.e. 7.99:1 and 8.31:1 in 2007-08 and 2008-09, respectively than neemarin. Highest yield of cabbage and benefit cost ratio was offered by neem azal during both the years. Neem excel exhibited II rank in yield production of cabbage but in benefit cost ratio it stands on V rank. Dichlorvos exhibited the II rank in benefit cost ratio but on V rank in yield performance in 2008-09. Whereas, it exhibited III rank in benefit cost ratio but stands on V rank in yield performance also in 2007-08. Although, cartap hydrochloride exhibited IV rank in benefit cost ratio but III in yield performance during both years. Biopesticides gave a better performance for the management of *P. xylostella* as compared to chemical insecticides.

Present studies revealed that neem formulations were significantly effective against *P. xylostella.* Almost similar results obtained by Patel *et al.* (1996). They reported that endosulfan 0.035 % (1:37.08), chlorpyriphos 0.02 % (1:34.08) and neem (*A. indica*) seed kernel suspension (NSKE) 3% (1:27.58) were the most effective against *P. xylostella* on cabbage. Dhaliwal *et al.* (1997-98) opined that the mortality of *P. xylostella* on cabbage was highest with 4 $kgha^{-1}$ of neem formulations, achook and nimbicidine 7 days after treatment and concluded that endosulfan was the most effective followed by achook and nimbicidie. They also reported that neem formulations were safer to the parasitoids, *Microplitis similis* and *Cotesia glomerata*. Javaid *et al.* (2000) compared the aqueous neem leaf and seed extracts with parallel dimethoate+cypermethrin against *P. xylostella* on cabbage and reported that neem formulations recorded significantly higher yield of marketable heads of cabbage and also significantly better control of *P. xylostella* than the commonly used mixture of pyrethroids or the untreated control. Lal and Meena (2001) reported that two foliar sprays of cartap hydrochloride at 15 days intervals starting from the appearance of the pest was the most effective treatment among all the insecticidal applications in both the cropping seasons followed by lambda-cyhalothrin, beta-cyfluthrin, ethofenprox, endosulfan and imidacloprid. These results are closely related to the results observed under present studies, where cartap hydrochloride exhibited better yield performance as well as benefit cost ratio and stands at III rank in yield performance and IV rank in benefit cost ratio among all the treatments. Kumar *et al.* (2007) reported that conventional insecticides enhanced yield significantly. However, azadirachtin was found to be better to control *P. xylostella* of cabbage. Murthy *et al.* (2006) found that indoxacarb, fipronil and NSKE were found to be effective in reducing the DBM population and recorded significantly higher marketable cabbage heads followed by soluneem, econeem plus, vijayneem and neemark. They also reported that the cost benefit ratio was highest for NSKE (1:9.58) treated plot followed by indoxacarb (1:8.25), fipronil (1:7.66), econeem plus (1:4.99) and vijayneem (1:4.41). These results are almost closely related to the results observed under present studies where, neem azal has given the highest benefit cost ratio (13.55:1, 14.02:1) during both years, respectively.

Table-5.1. Effect of biopesticides on the population of *P. xylostella* (2007-08)

Treatments	Conc. (%)	*Mean number of larvae and pupae/ plant					Percent reduction over control			
		1DBS	1DAS	3DAS	7DAS	10DAS	1DAS	3DAS	7DAS	10DAS
I round spray at 30 DAT										
Neem azal 0.50 EC	0.25	11.98 (3.53)	7.83a (2.89)	6.41a (2.63)	5.55a (2.46)	5.53a (2.46)	40.00	56.25	60.67	63.62
Neem excel 0.15 EC	0.25	11.85 (3.51)	8.28a (2.96)	6.67a (2.68)	5.82a (2.51)	5.75a (2.50)	36.55	54.47	58.75	62.17
Multineem 0.80 EC	0.25	11.72 (3.50)	9.21b (3.12)	7.02a (2.740	7.35b (2.80)	7.75c (2.87)	29.43	52.08	47.91	49.01
Neemarin 0.15 EC	0.25	11.78 (3.50)	9.23b (3.12)	7.92b (2.90)	8.03c (2.92)	8.36c (2.98)	29.27	45.94	43.09	45.00
Ultineem 0.30 EC	0.25	11.80 (3.51)	10.44c (3.31)	8.15b (2.94)	8.60c (3.02)	9.12d (3.10)	20.00	44.37	39.05	40.00
NSKE	4.00	11.90 (3.52)	10.15c (3.26)	9.13c (3.10)	9.75d (3.20)	10.33e (3.29)	22.22	37.68	30.90	32.04
Cartap Hydrochloride 50 SP	0.01	11.86 (3.52)	8.45a (2.99)	6.77a (2.70)	6.08a (2.57)	5.82a (2.51)	35.25	53.79	56.91	61.71
Dichlorvos 76 EC	0.01	11.83 (3.51)	8.33a (2.97)	6.97a (2.73)	6.84b (2.71)	6.63b (2.67)	36.16	52.42	51.52	56.38
Control	–	11.95 (3.53)	13.05d (3.68)	14.65d (3.89)	14.11e (3.82)	15.20f (3.96)	–	–	–	–
LSD P=0.05	–	NS	0.73	0.77	0.73	0.87	–	–	–	–
II round spray at 50 DAT										
Neem azal 0.50 EC	0.50	8.55a (3.01)	6.08a (2.57)	4.09a (2.14)	4.02a (2.13)	4.15a (2.16)	60.13	73.06	75.61	77.02
Neem excel 0.15 EC	0.50	8.90a (3.07)	6.21a -2.59	4.25a (2.18)	4.11a (2.15)	4.23a (2.17)	59.28	72.00	75.06	76.58
Multineem 0.80 EC	0.50	9.26b (3.12)	7.16b (2.77)	4.58a (2.25)	4.29a (2.19)	4.52a (2.24)	53.05	69.83	73.96	74.97
Neemarin 0.15 EC	0.50	10.07c (3.25)	8.02c (2.92)	6.67c (2.68)	6.72c (2.69)	6.89c (2.72)	47.41	56.06	59.22	61.85
Ultineem 0.30 EC	0.50	10.75d (3.35)	8.58c (3.01)	7.29c (2.79)	7.86d (2.89)	7.91d (2.90)	43.74	51.98	52.30	56.20
NSKE	5.00	13.50e (3.74)	12.23d (3.57)	9.03d (3.09)	9.62e (3.18)	9.94e (3.230	19.80	40.51	41.63	44.96
Cartap Hydrochloride 50 SP	0.02	8.47a (2.99)	6.93b (2.73)	4.43a (2.22)	4.15a (2.16)	4.26a (2.18)	54.55	70.82	74.82	76.41
Dichlorvos 76 EC	0.02	9.82b (3.21)	7.55b (2.84)	5.20b (2.39)	4.75b (2.29)	4.89b (2.32)	50.49	65.74	71.18	72.92
Control	–	14.89f (3.92)	15.25e (3.97)	15.18e (3.96)	16.48f (4.12)	18.06f (4.31)	--	–	–	–
LSD P=0.05	–	0.62	0.82	0.77	0.70	0.64	–	–	–	–

III round spray at 70 DAT										
Neem azal 0.50 EC	1.00	8.37a (2.98)	5.27a (2.40)	3.26a (1.94)	2.15a (1.63)	2.25a (1.66)	75.24	83.96	89.67	89.45
Neem excel 0.15 EC	1.00	8.62a (3.02)	5.56a (2.46)	4.05a (2.13)	2.65a (1.77)	2.77a (1.81)	73.88	80.08	87.27	87.02
Multineem 0.80 EC	1.00	9.19b (3.11)	7.69b (2.86)	5.20b (2.39)	3.89b (2.10)	4.15b (2.16)	63.87	74.42	81.31	80.55
Neemarin 0.15 EC	1.00	9.78b (3.21)	8.26b (2.96)	6.38c (2.62)	4.93c (2.33)	5.26c (2.40)	61.20	68.62	76.31	75.35
Ultineem 0.30 EC	1.00	10.90c (3.38)	8.47b (2.99)	6.65c (2.67)	5.22c (2.39)	5.83c (2.52)	60.21	67.29	74.92	72.68
NSKE	8.00	12.21d (3.57)	10.35c (3.29)	11.39d (3.45)	13.08d (3.69)	12.80d (3.65)	51.39	43.97	37.15	40.02
Cartap Hydrochloride 50 SP	0.05	8.56a (3.01)	6.10a (2.57)	4.72b (2.28)	3.42b (1.98)	3.68b (2.04)	71.35	76.78	83.57	82.76
Dichlorvos 76 EC	0.05	9.43b (3.15)	8.11b (2.93)	5.81c (2.51)	4.63c (2.26)	4.97c (2.34)	61.91	71.42	77.75	76.71
Control	–	20.65e (4.60)	21.29d (4.67)	20.33e (4.56)	20.81e (4.62)	21.34e (4.67)	–	–	–	–
LSD $P=0.05$	–	0.67	1.04	0.89	0.94	0.95	–	–	–	–

* Mean of 3 replicates figures within parentheses are $\sqrt{(x+0.5)}$ transformed values

Means followed by same letter in column are not significantly different ($P=0.05$) by DMRT

DBS- Days before spray DAS- Days after spraying DAT- Days after transplanting

Table 5.2. Effect of biopesticides on the population of *P. xylostella* (2008-09)

Treatments	Conc (%)	*Mean number of larvae and pupae/ plant					Percent reduction over control			
		1DBS	1DAS	3DAS	7DAS	10DAS	1DAS	3DAS	7DAS	10DAS
I round spray at 30 DAT										
Neem azal 0.50 EC	0.25	12.28 (3.57)	8.26a (2.96)	6.71a (2.69)	5.77a (2.50)	5.93a (2.54)	41.79	56.06	63.04	65.36
Neem excel 0.15 EC	0.25	12.35 (3.58)	8.56a (3.01)	6.91a (2.72)	6.35a (2.62)	5.65a (2.48)	39.68	54.75	59.32	67.00
Multineem 0.80 EC	0.25	12.32 (3.58)	8.93a (3.07)	7.34a (2.80)	7.59b (2.84)	8.09c (2.93)	37.07	51.93	51.38	52.75
Neemarin 0.15 EC	0.25	12.23 (3.57)	9.45b (3.15)	8.25b (2.96)	8.61c (3.02)	8.97c (3.08)	33.40	45.97	44.84	47.61
Ultineem 0.30 EC	0.25	12.49 (3.60)	10.60b (3.33)	8.33b (2.97)	8.94c (3.07)	9.52d (3.17)	25.30	45.45	42.73	44.39
NSKE	4.00	12.15 (3.56)	11.10c (3.41)	9.55c (3.17)	10.11d (3.26)	10.70e (3.35)	21.78	37.46	35.23	37.50
Cartap Hydrochloride 50 SP	0.01	12.55 (3.61)	8.72a (3.04)	7.18a (2.77)	6.85b (2.71)	5.90a (2.53)	38.55	52.98	56.12	65.54
Dichlorvos 76 EC	0.01	12.20 (3.56)	8.69a (3.03)	7.33a (2.80)	7.05b (2.75)	6.88b (2.72)	38.76	52.00	54.84	59.81
Control	–	12.18 (3.56)	14.19d (3.83)	15.27d (3.97)	15.61e (4.01)	17.12f (4.20)	–	–	–	–
LSD $P = 0.05$	–	NS	1.16	0.91	0.80	0.89	–	–	–	–
II round spray at 50 DAT										
Neem azal 0.50 EC	0.50	9.27a (3.13)	6.37a (2.62)	4.33a (2.20)	4.17a (2.16)	4.22a (2.17)	60.46	74.21	75.54	76.97
Neem excel 0.15 EC	0.50	9.38a (3.14)	6.71a (2.69)	4.69a (2.28)	4.39a (2.21)	4.60a (2.26)	58.35	72.07	74.25	74.89
Multineem 0.80 EC	0.50	10.66b (3.34)	7.45b (2.82)	5.11b (2.37)	4.65a (2.27)	4.85a (2.31)	53.76	69.57	72.73	73.53
Neemarin 0.15 EC	0.50	10.35b (3.29)	8.25b (2.96)	6.72c (2.69)	6.91c (2.72)	7.24c (2.78)	48.79	59.98	59.47	60.48
Ultineem 0.30 EC	0.50	11.10c (3.41)	9.16c (3.11)	7.48d (2.82)	8.02d (2.92)	8.31d (2.97)	43.14	55.45	52.96	54.64
NSKE	5.00	15.06d (3.94)	12.20d (3.56)	10.46e (3.31)	10.77e (3.36)	11.25e (3.43)	24.27	37.70	36.83	38.59
Cartap Hydrochloride 50 SP	0.02	9.81a (3.21)	7.05a (2.75)	4.72a (2.28)	4.47a (2.23)	4.79a (2.30)	56.24	71.89	73.78	73.85
Dichlorvos 76 EC	0.02	10.29b (3.28)	7.82b (2.88)	5.37b (2.42)	5.06b (2.36)	5.27b (2.40)	51.46	68.02	70.32	71.23
Control	–	15.06d (3.94)	16.11e (4.08)	16.79f (4.16)	17.05f (4.19)	18.32f (4.34)	–	–	–	–
LSD $P = 0.05$	–	0.71	0.91	0.75	0.87	0.77	–	–	–	–

III round spray at 70 DAT										
Neem azal 0.50 EC	1.00	8.42a (2.99)	4.41a (2.22)	2.75a (1.80)	1.87a (1.54)	1.90a (1.55)	75.16	87.16	91.50	91.86
Neem excel 0.15 EC	1.00	8.75a (3.04)	4.67a (2.27)	3.33a (1.96)	2.27a (1.66)	2.35a (1.69)	74.76	84.45	89.69	89.94
Multineem 0.80 EC	1.00	8.83a (3.05)	6.82c (2.71)	4.69b (2.28)	5.11c (2.37)	5.26c (2.40)	63.14	78.09	76.78	77.47
Neemarin 0.15 EC	1.00	10.06c (3.25)	7.45c (2.82)	5.77c (2.50)	5.92d (2.53)	6.17d (2.58)	59.73	73.05	73.10	73.58
Ultineem 0.30 EC	1.00	10.77c (3.36)	7.77d (2.88)	6.13d (2.57)	6.83e (2.71)	7.09d (2.75)	58.00	71.37	68.97	69.64
NSKE	8.00	13.65d (3.76)	10.89e (3.37)	10.82e (3.36)	11.05f (3.40)	11.24e (3.43)	41.14	49.46	49.80	51.86
Cartap Hydrochloride 50 SP	0.05	8.85a (3.06)	5.29b (2.41)	3.76b (2.06)	3.26b (1.94)	3.59b (2.02)	71.41	82.44	85.19	84.63
Dichlorvos 76 EC	0.05	9.21b (3.12)	5.26b (2.40)	5.02c (2.35)	4.90c (2.32)	5.20c (2.39)	71.57	76.55	77.74	77.73
Control	–	18.55e (4.36)	18.50f (4.36)	21.41f (4.68)	22.01g (4.74)	23.35f (4.88)	–	–	–	–
LSD $P=0.05$	–	0.76	0.82	0.95	0.77	0.93	–	–	–	–

* Mean of 3 replicates figures within parentheses are $\sqrt{(x+0.5)}$ transformed values

Means followed by same letter in column are not significantly different ($P=0.05$) by DMRT

DBS- Days before spray DAS- Days after spraying DAT- Days after transplanting

Table 5.3. Economics of treatments for management of *P. xylostella* on cabbage (2007-08)

Treatments	*Marketable yield (q ha^{-1})	Total Quantity of Biopesticides (Lit. ha^{-1})	Increased yield over control (q ha^{-1})	Increased Return (Rs ha^{-1})	Cost of treatment (Rs ha^{-1})	Benefit of treatment (Rs ha^{-1})	Benefit cost Ratio
Neem azal 0.50 EC	281.73e	3.50	69.30	41,580.00	2,858.00	38,722.00	13.55:1
Neem excel 0.15 EC	276.85d	5.83	64.42	38,652.00	3,191.00	35,461.00	11.11:1
Multineem 0.80 EC	271.48d	2.19	59.05	35,430.00	2,623.00	32,807.00	12.51:1
Neemarin 0.15 EC	260.11c	5.83	47.68	28,608.00	3,249.00	25,359.00	7.81:1
Ultineem 0.30 EC	258.75b	2.92	46.32	27,792.00	2,405.00	25,387.00	10.56:1
NSKE	249.90b	1,500	37.47	22,482.00	2,500.00	19,982.00	7.99:1
Cartap Hydrochloride 50 SP	273.18d	1.60	60.75	36,450.00	2,944.00	33,506.00	11.38:1
Dichlorvos 76 EC	267.55c	1.04	55.12	33,072.00	2,504.00	30,568.00	12.21:1
Control	212.43a	–	–	–	–	–	–
LSD $P=0.05$	10.06	–	–	–	–	–	–

Price of cabbage @ Rs. 600/- q^{-1} Cost of preparation and spraying of NSKE ha^{-1} = RS. 2,500.00

Table 5.4. Economics of treatments for management of *P. xylostella* on cabbage (2008-09)

Treatments	*Marketable yield (q ha^{-1})	Total Quantity of Biopesticides (Lit. ha^{-1})	Increased yield over control (q ha^{-1})	Increased Return (Rs ha^{-1})	Cost of treatment (Rs ha^{-1})	Benefit of treatment (Rs ha^{-1})	Benefit cost Ratio
Neem azal 0.50 EC	275.62e	3.50	68.02	44,893.00	2,988.00	41,905.00	14.02:1
Neem excel 0.15 EC	269.18d	5.83	61.58	40,643.00	3,395.00	37,248.00	10.97:1
Multineem 0.80 EC	264.35d	2.19	56.75	37,455.00	2,723.00	34,732.00	12.76:1
Neemarin 0.15 EC	253.81c	5.83	46.21	30,499.00	3,541.00	26,958.00	7.61:1
Ultineem 0.30 EC	250.57b	2.92	42.97	28,360.00	2,434.00	25,926.00	10.65:1
NSKE	244.28b	1,500	36.68	24,209.00	2,600.00	21,609.00	8.31:1
Cartap Hydrochloride 50 SP	266.45d	1.60	58.85	38,841.00	2,960.00	35,881.00	12.12:1
Dichlorvos 76 EC	260.77c	1.04	53.17	35,092.00	2,530.00	32,562.00	12.87:1
Control	207.60a	–	–	–	–	–	–
LSD $P=0.05$	8.69	–	–	–	–	–	–

Price of cabbage @ Rs. 660/- q^{-1} Cost of preparation and spraying of NSKE ha^{-1} = RS. 2,600.00

* Mean of 3 replicates

Means followed by the same letter in column are not significantly different (P=0.05) by DMRT

Plate 4
A-Control plot showing infestation on Cabbage-NS-25 by *P. xyolostella*
B-Effect of Neem azal 0.50 EC on Cabbage-NS-25 against *P. xyolostella*
C-Effect of Neem excel 0.15 EC on Cabbage-NS-25 against *P. xyolostella*

Plate 5.
A-Effect of Multineem 0.80 EC on Cabbage-NS-25 against *P. xyolostella*
B-Effect of Neemarin 0.15 EC on Cabbage-NS-25 against *P. xyolostella*
C-Effect of Ultineem 0.30 EC on Cabbage-NS-25 against *P. xyolostella*

Plate 6.
A-Effect of NSKE on Cabbage-NS-25
against *P. xyolostella*
B-Effect of Cartap hydrochloride 50 SP on Cabbage-NS-2
against *P. xyolostella*
C-Effect of Dichlorvos 76 EC on Cabbage-NS-25
against *P. xyolostella*

CONCLUSION

Diamondback moth, *Plutella xylostella* (Linn.) (Lepidoptera: Yponomeutidae) is a major insect pest of *Brassica* crops. It thrives under extremely varied climatic conditions prevailing in different parts of India. Population dynamics of *P. xylostella* was studied on six varieties of cabbage, *B. oleracea.* var. *capitata*; Field Man, F1 Deepti, Hybrid-1080, Golden Acre, Cabbage-NS-25 and Diamond Express during Rabi season from October 2007 to April, 2008 and October, 2008 to April, 2009 at 3 locations in the farmer's fields of Aligarh district; Jalali, Mathura Road and G.T. Road which are major cultivating areas of cabbage. Initial intensity of *P. xylostella* i. e. 0.32 and 0.76 larvae and pupae/plant was observed at 40 and 41 std. weeks in 2007 and 2008, respectively on Field Man at Jalali. Percent parasitization ranged between 2.44 to 43.70 from 41 to 9 std. weeks and 1.57 to 30.18 percent from 42 to 8 std. weeks. Intensity was 1.16 to 6.04 and 0.95 to 5.79 larvae and pupae/plant on F1-Deepti with 7.31 to 59.33 and 2.62 to 57.61 percent parasitization from 40 to 8 and 40 to 9 std. weeks, respectively during both years of study at the same location. Density of *P. xylostella* ranged between 1.45 to 9.25 larvae and pupae/plant with 2.99 to 45.45 percent parasitization from 47 to 11 std. week and 1.28 to 11.66 larvae and pupae/plant with 11.33 to 87.96 percent parasitization from 45 to 10 std. week was observed on Hybrid-1080 in 2007-08 at Mathura Road. While, intensity ranged from 2.09 to 12.47 larvae and pupae/plant with 1.18 to 29 percent parasitization at 47 to 13 std. week and 1.08 to 12.56 larvae and pupae/plant with 7.26 to 46.34 percent parasitization was recorded from 45 to 13 std. week in 2007-08 and 2008-09, respectively on Golden Acre at the same location. Population of *P. xylostella* i.e. 1.75 to 19.67 larvae and pupae/plant with 4.06 to 62.33 percent parasitization was recorded from 50 to 15 std. weeks on cabbage-NS-25 and 2.15 to 25.80 larvae and pupae/plant with 1.23 to 24.70 percent parasitization was monitored from 51 to 17 std. week on Diamond Express in 2007-08 at G. T. Road. Whereas, 2.45 to 24.13 larvae and pupae/plant with 17.81 to 59.52 percent parasitization was from 49 to 14 std. weeks on cabbage-NS-25 and 2.55 to 24.50 larvae and pupae/plant with 10.35 to 46.63 percent parasitization was observed from 52 to 17 std. weeks on Diamond Express in 2008-09 at the same location.

During the period of study of two cropping seasons of 2007-08 and 2008-09, temperature was fluctuating between 10.97° to 29.79°C with relative humidity of 42.29 to 85.0 percent and scanty rainfall of 0.40 to 11.60mm while, temperature ranged from 11.90° to 31.58°C with relative humidity of 11.86 to 94.0 percent and with scanty rainfall of 0.80 to 12.0 mm, respectively. Comparatively lower population of DBM was observed in 2007-08 than in 2008-09 and scanty rainfall favoured the pest population build up during both years.

Cotesia plutellae (Kurdjumov) was found to be predominant parasite in the study area. Parasitism was reached to 43.70 and 59.33 percent at 2 and 51 std. weeks on Field Man and F1-Deepti, respectively in 2007-08 at Jalali. It was increased to 87.96 percent at 4 std. weeks of 2009 on Hybrid-1080 at Mathura Road while 62.33 percent at 12 std. weeks of 2008 at a temperature ranged between 16.21° to 32.0°C with relative humidity of 59.14 to 68.43 percent with scanty rainfall of 0.50mm on Cabbage-NS-25 at G.T. Road.

Oviposition behaviour of *P. xylostella* was studied on six varieties of cabbage (*B. oleracea var. capitata*) i.e. Diamond Express, Hybrid-1080, F1 Deepti, Field Man, Golden Acre and Cabbage-NS-25 and three varieties of Indian mustard (*Brassica juncea*) i.e. Pusa Bold, Varuna and Pusa Bahar under choice and no-choice tests of 2007-08 and 2008-09 under protected field condition. Female of *P. xylostella* significantly preferred to oviposit on cabbage as compared to Indian mustard in both choice and no-choice tests. While, Diamond Express of cabbage was more preferred host than that of Hybrid-1080, Golden Acre, F1-Deepti and Field Man in both choice and no-choice tests. Pusa Bold of Indian mustard is more preferred over Varuna and Pusa Bahar in both choice and no-choice tests. Average number of eggs /5females ranged between 14.25 to 16.25 and 109.27 to 138.20 in both choice and no-choice tests, respectively on Indian mustard varieties which were significantly (*$P<0.05$*) similar during mean of both years, but significantly differed ranged from 25.01 to 73.31 in choice test on cabbage varieties. 204.09 to 623.66 eggs/5 females were ranged on cabbage varieties in no choice test, while F1-Deepti and Field Man were same but rest of the four varieties were significantly differed in no-choice test in mean of both years.

Feeding behavior of larvae of *P. xylostella* was significantly/non significantly differed on cabbage and Indian mustard in both choice and no-choice tests during both years of study. Highest leaf area consumed by the larva of *P. xylostella* was i.e. 15.05, 15.77 cm^2 and 14.97, 15.94 cm^2 and the lowest i.e. 6.21, 7.59 cm^2 and 6.03, 8.83 cm^2 on Diamond Express and Field Man in both choice and no-choice tests during 2007-08 and 2008-09, respectively. Whereas, larva of *P. xylostella* preferred to feed more on Pusa Bold than Varuna and Pusa Bahar of Indian mustard in both tests during both years of study.

Diamond Express is highly preferred/susceptible variety of cabbage for *P. xylostella* followed by Hybrid-1080, Cabbage-NS-25, Golden Acre, F1-Deepti and Field Man.

Larval survival of *P. xylostella* was studied under protected field condition (choice and no-choice tests) and at constant temperatures i.e. 10°, 15°, 20°, 25° and 30°C on six *Brassica* hosts; three cabbage varieties: Field Man, Golden Acre, Diamond Express and three Indian mustard; Pusa Bold, Varuna and Pusa Bahar. Larval survival was found to be highest i.e. 80.58 and 82.76 percent on Diamond Express and smallest on Pusa Bahar i.e. 30.84 and 47.76 percent in 2007-08 in both choice and no-choice tests, respectively. Whereas, it was 83.12 and 81.06 percent on Diamond Express and least i.e. 33.39 and 49.26 percent on Pusa Bahar in both tests, respectively in 2008-09.

Larval survival of *P. xylostella* is considerably affected by *Brassica* hosts at constant temperatures. Survival was highest on Diamond Express and the lowest on Field Man on cabbage at all temperatures tested. Larval survival was smaller (12.88 percent) on Pusa Bahar than that of Varuna and Pusa Bold at 10°C. Larval survival was higher at 20°C on cabbage and Indian mustard varieties as compared to other temperatures.

Life table of *P. xylostella* was studied on *Brassica* hosts; three cabbage and three Indian mustard varieties at 22±1°C and 70±5% relative humidity. Survivorship was greater on cabbage varieties than on Indian mustard. Highest number of eggs were hatched on cabbage i.e. Diamond Express followed by Golden Acre and Field Man as compared to Indian mustard. Mortality of egg was highest when *P. xylostella* reared on Pusa Bahar and lowest on Diamond Express. Mortality also occurred at different stages of *P. xylostella* and larval mortality was more on Indian mustard than cabbage varieties and least on Diamond Express. Duration of immature stages from egg to pupa was 25 days on Indian mustard and prolonged to 27 days on Diamond Express. Adult emergence was highest on cabbage i.e. Diamond Express followed by Golden Acre and Field Man as compared to Indian mustard. The greatest expectancy of life was recorded on cabbage i.e. Diamond Express followed by Golden Acre and Field Man as compared to Indian mustard varieties i.e. on Varuna followed by Pusa Bahar and Pusa Bold.

Pre-oviposition period lasted for one day in all the host plants. *P. xylostella* preferred to lay more eggs on cabbage varieties i.e. Diamond Express than other varieties of cabbage and Indian mustard. Total oviposition period was 8-days on Indian mustard while, 9, 10 and 11 days on Field Man, Golden Acre and Diamond Express, respectively. Highest potential fecundity (*Pf*) occurred on Diamond Express i.e. 124.05 and lowest on

Pusa Bahar i.e. 52.42 females/female/generation followed by on Golden Acre (90.56), Field Man (75.20), Pusa Bold (63.57) and Varuna (55.87). Highest net reproductive rate (*Ro*) i.e. 64.99 females/female/generation was obtained on Diamond Express and lowest i.e. 7.78 on Varuna. Highest intrinsic rate of increase (r_m) i.e. 0.049 females/female/day occurred on Golden Acre and lowest i.e. 0.027 on Varuna followed by Diamond Express and Pusa Bold. r_m is significantly ($P<0.05$) reduced when *P. xylostella* reared on Indian Mustard. Lowest finite rate of increase (λ) i.e. 1.027 females/female/day was found on Varuna and highest on Golden Acre i.e. 1.050. Corrected generation time of *P. xylostella* (τ) was 38.01 days on Diamond Express followed by Golden Acre and Field Man. While, fractional difference was recorded on Pusa Bold, Varuna, Field Man and Golden Acre. *P. xylostella* multiplies fast on cabbage varieties as compared to Indian mustard.

Cabbage was intercropped with radish, carrot, tomato, garlic, cumin, fennel, coriander, berseem and marigold studied in two cropping seasons of 2007-08 and 2008-09. Population of *P. xylostella* increases from 10 to 70 DAP (days after transplantation) then gradually decreases up to harvesting of crop during both years. Peak population of *P. xylostella* was observed at 70 DAP on cabbage in 2008-09. 15:2 ratio of lines of cabbage+tomato was found to be superior in reducing the incidence of *P. xylostella* on cabbage as compared to 15:1, 25:1 and 25:2 ratio of lines of cabbage+intercrops; radish, carrot, garlic, cumin, fennel, coriander, berseem and marigold. It was followed by garlic, cumin, fennel and coriander. Spacing of cabbage (50x40cm) with intercrops holds more population of DBM larvae and pupae/plant than spacing of 60x45cm. 40-days old seedling of cabbage when planted along with intercrops showed a reduction in larval and pupal population of *P. xylostella* than planting of 30-days old seedling of cabbage in both years of study.

Higher parasitisation was recorded in 30-days old seedling of cabbage than 40-days old seedling and in 60x45 cm spacing than 50x40cm and also in 15:1 ratio than 15:2 during both cropping years. Similarly 25:1 ratio attracted more number of parasitoids than 25:2 ratios in both the seedling stages and in all the spacing schedules. Significantly highest parasitisation was observed in cabbage + tomato intercrop (23.64 to 60.71 percent) as compared to other cropping system during both years of study. Cabbage + berseem cropping system attracted a considerably lower number of parasites as compared to other intercropping system. Occurrence of parasitoids in cabbage intercropped with garlic, cumin, fennel and coriander was significantly higher as compared to radish, carrot, berseem and marigold cropping system. *C. plutellae* was observed dominant larval parasitoids in the experimental field during both the years.

The highest yield increase was in a range of 47.17 to 61.34 q^{-h} cabbage + tomato cropping system and the lowest i.e. 6.30 to 15.00 q^{-h} in cabbage + marigold as compared to cabbage alone. 40-days old seedling of cabbage when planted produced greater yield than 30-days old in all ratios and spacing schedules during both years. Spacing of 60x45 cm with a ratio of 15:2 (cabbage + intercrops) produced higher yield of sole and intercrops than that ratio of 15:1 and also on the same way 25:2 produced maximum yield rather than 25:1. Minimum yield was recorded on cabbage + marigold cropping system in relation to stage of seedling, ratio and spacing. Maximum benefit in terms of rupees was estimated on cabbage + tomato cropping system i.e. Rs. 40870/- in 30-days old seedling of cabbage with 60x45cm spacing and 15:2 ratio during 2007-08. While, it was estimated as Rs. 46440/- in 40-days old seedling of cabbage with the same spacing and ratio in 2008-09 as compared to other cropping system. Cumin, fennel, garlic and coriander intercrops offered greater additional return as compared to radish, carrot, berseem and marigold during both years of study. Comparatively higher yield was recorded in 2007-08 than in 2008-09.

Weather parameters are significantly/non significantly (positively/negatively) correlated in both years of study. Maximum and minimum temperature, average humidity and rainfall is non significantly (positively/negatively) correlated with ratios and spacing and both seedling stages during both seasons except maximum temperature which was significantly negative in 40-days old seedling of cabbage with 25:1 and 25:2 and 60x45 cm of spacing in 2007-08. Minimum temperature was also substantially affected the population of *P. xylostella* in 2007-08 and negligible rainfall was recorded in experimental period of 2007-08. In 2008-09, rainfall substantially affected the population of *P. xylostella.* Environmental conditions caused a significant/non significant effect on the perpetuation of *C. plutellae* during both 2007-08 and 2008-09. Maximum and minimum temperature significantly (P < 0.01, P < 0.05) enhanced the population of *Cotesia* in 30 and 40-days old seedling of cabbage.Therefore, it is concluded that 15 lines of 40-days old seedling of cabbage with 60x45 cm spacing along with 2 lines of tomato as an intercrop was found significantly effective in reducing the incidence of *P. xylostella.*

Biopesticides viz. neem azal, neem excel, multineem, neemarin, ultineem, NSKE, cartap hydrochloride and dichlovos were tested against *P. xylostella* on cabbage and offered a significant (P<0.05) reduction in larvae and pupae of *P. xylostella* at 1, 3, 7 and

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10 days after treatment over control. Neem azal 0.50% was significantly ($P<0.05$) the best treatment followed by neem excel 0.15% and cartap hydrochloride 50 SP against *P. xylostella* in all the spraying schedules during both years of 2007-08 and 2008-09. Application of neem azal @ 0.25, 0.50 and 1.00% at 30, 50 and 70 days after transplantation (DAT) was found most effective registering 40.0-63.62%, 60.13-77.02% and 75.24-89.45% reduction in the population of *P. xylostella* as compared to control in 2007-08. Whereas, 41.79-65.36%, 60.46-76.97% and 75.16-91.86% reduction was obtained in larval population over control in all three round sprays, respectively in 2008-09. Neem azal and neem excel were similar in efficacy during both years of study. All the treatments produced significantly ($P<0.05$) higher marketable yield of cabbage as compared to control during both years of study. Maximum yield was produced in neem azal i.e. 281.73 and and 275.62 qha^{-1} in 2007-08 and 2008-09, respectively followed by neem excel cartap hydrochloride and multineem. Lowest yield i.e. 212.43 and 207.60 qha^{-1} of cabbage was recorded in control plot in 2007-08 and 2008-09, respectively. Yield of cabbage in ultineem and NSKE were statistically similar. Yield from neemarin and dichlorvos was also same in both years of study. Neem azal exhibited the highest benefit cost ratio i. e. 13.55:1and 14.02:1 in 2007-08 and 2008-09, respectively. Neemarin showed the lowest benefit cost ratio i.e. 7.81:1and 7.61:1 during both years. Therefore, it is concluded that application of neem azal 0.50EC @ 0.25, 0.50 and 1.00% at 30, 50 and 70 days after transplantation gave highest yield of cabbage as well as highest benefit cost ratio during both years.

REFERENCES

Abraham, E.V. and Padmanabhan, M.D. (1968). Bionomics and control of the DBM, *Plutella xylostella. Ind. J. Agric. Sci.,* 38:513-519.

Abro, G.H., Jayo, A.L. and Syed, T.S. (1994). Ecology of diamondback moth, *Plutella xylostella* (L.) in Pakistan 1. Host plant preference. *Pak. J. Zool.* 26:35–38.

Adams, D.B. (1991). On farm components of diamondback moth management in Georgia, USA.

Agerbirk, N., Olsen, C.E., Bibby, B.O., Frandsen, H.O., Brown, L.D., Nielsen, J.K. and Renwick, A.A. (2003). A saponin correlated with variable resistance of *Barbarea vulgaris* to the diamondback moth, *Plutella xylostella. J. Chem. Ecol.*, 29:1417–1433.

Ahmad, T. (2008). Studies on bionomics and management of Diamondback Moth, *Plutella xylostella* (Linn.) on cauliflower, *Brassica olearacea* var. *botrytis* L. *Ph.D. thesis*, submitted to the Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India.

Ahmad, T. and Ansari, M.Shafiq (2010). Studies on seasonal abundance of Diamondback Moth *Plutella xylostella* (Lepidoptera:Yponomeutidae) on cauliflower crop. *J. Pl. Protec. Res.,* 50 (3):280-287.

Ahmad, T., Ansari, M.Shafiq and Ali, Haidar (2009). Outbreak of Diamondback Moth, *Plutella xylostella* in Aligarh, India. *Trends Biosci.,* 2(1):10-12

Ahmad, Tufail, Ansari, M. Shafiq, Ali, Haidar and Nazrussalam (2008). Oviposition preference of *Plutella xylostella* on *Brassica* cultivars. *J. Ecofriendly Agric.*, 3 (2):157-159.

Akhtar, Y., and Isman, M.B. (2003). Binary mixtures of feeding deterrents mitigate the decrease in feeding deterrent response to antifeedants following prolonged exposure in the cabbage looper, *Trichoplusia ni* (Lepidoptera: Noctuidae). *Chemoecology*. 13:177-182.

Alam, M.M. (1982). Cabbage pests and their natural enemies in Barbados, *West Indies Proc. 18th CFCS*, Barbados, 22-28 Aug. 1982, 307-319*pp*

Alam, M.M. (1991). Diamondback moth and its natural enemies in Jamaica and some other Caribbean Islands. In N. S. Talekar (ed.), Management of diamondback moth and other crucifer pests: *Proc. II Interntl. Workshop,* A.V.R.D.C., Shanhua, Taiwan, 233-243*pp*

Al-Doghairi, M.A. and Cranshaw, W.S. (2004). The effect of interplanting of necteriferous plants on the population density and parasitism of cabbage pests. *Southwest Entomol.,* 29(1):61-68.

Al-Fifi, Z.I.A. (2009). Effect of Different Neem Products on the Mortality and Fitness of Adult *Schistocerca gregaria* (Forskal). *J.K.A.Univ.,* 21(2):299-315.

Ali, Haidar and Ansari, M.S. (2008). Influence of intercropping on the incidence of *Lipaphis erysimi* (Kaltenbach) in mustard. *Trends Biosci.*, 1(1, 2):31-33.

Ali, M.I., and Bakshi, A.I. (1994). Management strategy for the diamondback moth and the tobacco caterpillar on cabbage in Bangladesh. *Bangladesh J. Entomol.,* 4:9-16.

Altmann, J.A. (1988). An investigation of resistance in cabbage moth, *Plutella xylostella* (L.) to pyrethroids in the Lockyer Valley. *Graduate Dip.Thesis, Queensland Agric.College*, Lowes, Queensland, Australia.

Andrahennadi, R. and Gillott, C. (1998). Resistance of *Brassica*, especially *B. juncea* (L.) Czern, genotypes to the diamondback moth, *Plutella xylostella* (L.). *Crop Protec.*, 17:85-94.

Andrewartha, H.G. and Birch, L.C. (1954). The Distribution and Abundance of Animals. *Ann. Rev. Entomol.*, 15:1-24.

Anonymous (1968). Distribution Map of Pests, *Plutella xylostella* (L.). *Commonwealth Instt., Entomol.,* CAB, Series A. Mp No.32.3.

Anonymous (1985). Intercropping for diamondback moth control. *Prog. Report.* A.V.R.D.C., Shanhua, Taiwan.

Anonymous, (1998). *Annual Progress Report*: A.V.R.D.C., Shanhua, Taiwan.

Anonymous, (2005). Production share of major vegetables in India. *Ind. Hort. Database, 2005.*

Ansari, M.Shafiq, Ahmad, T. and Ali, H.(2010). Effect of Indian mustard varieties on feeding, larval survival and development of *Plutella xylostella* at constant temperatures. *Entomol. Res.*, 40:182-188.

Araiza, M.D.S., Mojica, H.B., Arriaga, J.T. and Rosas, R.A. (1990). Preferencia de *Plutella xylostella* (Lepidoptera: Plutellidae) por cruciferas cultivadas Y silvestres. *Agrociencia Series Protec. Veg.,* 1:33-42.

Arora, R. and Dhaliwal, G.S. (1994). Botanical pesticides in insect pest management. *Management of Agricultural Pollution in India.* Commonwealth Pub., New Delhi, India. 213-245*pp*

Asman, K. (2002). Trap cropping effect on oviposition behaviour of the leek moth, *Acrolepiopsis assectella* and the diamondback moth, *Plutella xylostella. Entomol. Exptl. Appl.,*105(2-3):153-164.

Asman, K. and Ekbom, B. (2006). Responses of ovipositing moths to host plant deprivation: life history aspects and implications for intercropping. *Agric. Forest Entomol.,* 8(3):213-219.

Asman, K., Barbara, E. and Birgitta, R.M. (2001). Effect of intercropping on oviposition and emigration behaviour of the leek moth (Lepidoptera: Acrolepiidae) and the diamondback moth (Lepidoptera: Plutellidae). *Environ. Entomol.*, 30(2):288-294.

Auad, A.M. and Moraes, J.C. (2003). Biological aspects and life table of *Uroleucon ambrosiae* (Thomas, 1878) as a function of temperature. *Sci. Agricola,* 60(4):657-662.

Ayalew, Gashawbeza., Baumgartner, Johan. Ogol., Callistus., K.P.O. and Lohr, Bernharda (2006). Analysis of population dynamics of diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae)) at two sites in central Ethiopia, with particular reference to parasitism. *Biocon. Sci. Tech.,* 16(6):607-618.

Bach, C.E. (1980). Effects of plant diversity and time of colonization on an herbivore plant interaction. *Oecologia,* 44:319-326.

Bach, C.E. and Tabashnik, B.E. (1990). Effects of non-host plant neighbors on population densities and parasitism rates of the diamondback moth (Lepidoptera:Plutellidae). *Environ. Entomol.,* 19 (4):987-994.

Badenes-Perez., Francisco R., Shelton, A.M. and Nault, B.A. (2004). Evaluating trap crops for diamondback moth, *Plutella xylostella* (Lepidoptera:Plutellidae). *J. Econ. Entomol.,* 97(4):1365-1372.

Badenes-Perez., Francisco, R., Nault, B.A. and Shelton, A.M. (2006). Dynamics of diamondback moth oviposition in the presence of a highly preferred non-suitable host. *Entomol. Exptl. Appl.,* 120(1):23-31.

Badenes-Perez., Francisco, R., Nault, B.A. and Shelton, A.M. (2005a). Manipulating the attractiveness and suitability of hosts for diamondback moth (Lepidoptera:Plutellidae). *J. Econ. Entomol.,* 98(3):836-844.

Badenes-Perez., Francisco, R., Shelton, A.M. and Nault, B.A. (2005b). Using yellow rocket as a trap crop for diamondback moth (Lepidoptera:Plutellidae). *J. Econ. Entomol.*, 98(3):884-890.

Baker E.A. (1974). The influence of environment of leaf wax development in *Brassica oleracea var. gemmifera. New Phytol.*, 73:955-966.

Barker, A.M. and Maczka, C.J.M. (1996). The relationship between host selection and subsequent larval performance on three free-living graminivorous sawflies. *Ecol. Entomol.*, 21:317-327.

Begum, S., Ritsuko, T., Fujisaki, K. and Nakasuji, F. (1996). The effects of wild cruciferous host plants on morphology, reproductive performance and flight activity in the diamondback moth, *Plutella xylostella* (Lepidoptera: Yponomeutidae). *Res.Popul. Ecol.* 38:257–263.

Bell, P.D. and Fenemore, P.G. (1990).Insecticide resistance in diamondback moth in New Zealand. *Proc.* 43rd *New Zealand Weed and Pest Cont. Conf.*, 31-34*pp*

Bender, D.A., Morrison, W.P. and Kern, J.R. (1999). Intercropping cabbage and Indian mustard for potential control of lepidopterous and other insects. *Hort. Sci.*, 34:275–79.

Bernays, E.A. and Chapman, R.F. (1994). Behavior: The process of host finding in host plant selection by phytophagous insects. *Chapman and Hall,* New York, 95–116*pp*

Bhalla, O.P. and Dubey, J.K. (1986). Bionomics of the diamondback moth in the North Western Himalaya. In N. S. Talekar (ed.), Management of diamondback moth and other crucifer pests: *Proc. I Interntl. Workshop,* Tainan, Taiwan, 11-15 March, 1985. 55-61*pp*

Bilapate, G.G., Pawar, V.M. and Gaikwad, B.B. (1978). The rate of increase in numbers of *Heliothis armigera* on green lima beans. *J. Maharastra Agric.Univ.*, 3:38-39.

Birch, L.C. (1948). The intrinsic rate of natural increase of an insect population. *J. Anim. Ecol.,* 17: 15-20.

Broughton, H.B., Ley S.V., Slawin, A.M.Z., Williams, D.J. and Morgan, E.D. (1986) X-ray crystallographic structure determination of detigloyldihydro-azadirachtin and reassignment of the structure of limonoid insect antifeedant, azadirachtin. *J. Chem. Soc. Chem. Commun.*, 46-47.

Broughton, H.B., Ley, S.V., Morgan, E.D., Z-Slawin, A.M. and Williams, D.J. (1986). The chemical structure of Azadirachtin. *Proc. 3rd Interntl. Neem Conf.* (Nairobi, 1986) Abs. 20*pp*

Bukovinszky, T., Potting, R.P.J., Clough, Y., Van Lenteren, J.C. and Vet, L.E.M. (2005). The role of pre and post-alighting detection mechanisms in the responses to patch size by specialist herbivores. *Oikos*, 109:435–446.

Buranday, R.P. and Raros, R.S. (1975). Effects of cabbage-tomato intercropping on the incidence and oviposition of the diamondback moth, *Plutella xylostella* (L.). *Philipp. Entomol.*, 2:369-374.

Butterworth, J.H. and Morgan, E.D. (1971). Investigation of the locust feeding inhibition of the seeds of neem tree *Azadirachta indica. J. Insect Phsiol.* 17:969-977.

Butterworth, J.H. and Morgan, E.D. (1968). Isolation of a substance that suppresses feeding in locusts. *J Chem Soc. Chem Commun.*, 1968:23-24.

Butts, R.A. and McEwen, F.L. (1981). Seasonal population of the diamondback moth, *Plutella xylostella* (Lepidoptera:Plutellidae) in relation to day-degree accumulation. *Can. Entomol.*, 113(2):127-131.

Campos, W.G., Schoereder, J.H. and DeSouza, O.F. (2006). Seasonality in Neotropical populations of *Plutella xylostella* (Lepidoptera): Resource availability and migration. *Pop. Ecol.* 48: 151-158.

Carballo, V.M., and Hruska, A.J. '(1989). Critical period of protection and effect of infestation by *Plutella xylostella* L. (Lepidoptera:Plutellidae) on the yield of cabbage. *Manejo-Integrado- de Plagas.* 14:46-60.

Chandramohan, N. (1994). Seasonal incidence of diamondback moth, *Plutella xylostella* L. and its parasitoids in Nilgiris. *J. Biol. Cont.*, 8:77- 80.

Charleston, D.S. and Kfir, R. (2000). The possibility of using Indian mustard as a trap crop for the diamondback moth in South Africa. *Crop Protec..*, 19:455-460.

Chauhan, U. and Sharma K.C. (2002). Status of biocontrol agents of *Plutella xylostella* (L.) (Lepidoptera: yponomeutidae) in hilly regions of the North-West Himalayas, India In: Kirk, A.A., Bordat, D. (Eds.), *Proc. Interntl. Symp.* 21–24 October 2002, Montpellier, France, C.I.R.A.D., 204-211.

Chelliah, S. and Srinivasan, K. (1986). Bio-ecology and management of diamondback moth in India. Management of diamondback moth and other crucifer pests. *Proc. 1st Interntl. Workshop.* A.V.R.D.C.,Tainan, Taiwan, 4 : 11-15.

Chen, C.N. and Su, W.Y. (1986). Ecology and control thresholds of diamondback moth on crucifers in Taiwan. Management of diamondback moth and other crucifer pests. *Proc.1st Interntl. Workshop.*, A.V.R.D.C.,Tainan, Taiwan 4:415-421.

Choi, I.H., Yoo, J.K. and Na, S.Y. (1992). Studies on the ecological characteristics and effect of chemical control on diamondback moth, *Plutella xylostella* (L.) *Res. Rep. Rural Dev. Adv. Crop Protec.*, 34(1):40-47.

Chung, B.K., Park, C.G., Cho, D.J. and Shin, W.K. (1989). Influence of temperature on the development, fecundity and longevity of diamondback moth, *Plutella xylostella* (L.) *Res. Rep. Rural Dev. Adv. Crop Protec.*, 31(4):30-37.

Deevey, E. S. (1947). Life table for natural populations of animals. *Quart. Rev. Biol.*, 22: 283-314.

Devi, N. and Raj, D. (1995). Biology and parasitization of diamondback moth, *Plutella xylostella* (L.) infesting cauliflower in mid hill region of Himachal Pradesh (India). *J. Entomol. Res.*, 19(1):83-86.

Devjani, P. (1999). Bioecology and control of insect pests of cauliflower in Manipur. *Ph. D. Thesis.* Manipur University, Manipur.

Devjani, P. and Singh, T.K. (1999). Field density and biology of diamondback moth, *Plutella xylostella* L. (Lepidoptera:Plutellidae) on cauliflower in Manipur. *J. Adv. Zool.*, 20(1):53-55.

Dhabi, M. R., Mehta, D. M., Patel, C. C. and Korat, D. M. (2009). Life table of Diamondback moth, *Plutella xylostella* on cabbage. *Karnataka J. Agric. Sci.*, 22(2):319-321.

Dhaliwal, G.S., Gill, R.S., and Dilawari, V.K. (1997). Management of insect pest complex of cabbage with neem based insecticides. *Ecol. Agric. Sustainable Dev.*, 2:306-314.

Dhaliwal, H. S. and Goma, B. O. (1979). Seasonal abundance of various insect pests on cauliflower seed crop in the lower hills of Solan. *Ind. J. Ecol.* 6:101-109.

Dixon, A.F.G. (1987). Parthenogenetic reproduction and the rate of increase in aphids. In: Minks, A.K. and Harrewijn, P. (eds.) Aphids: their biology, natural enemies and control, Vol. A. *Elsevier,* Amsterdam, The Netherlands. 269-287*pp*

Dickson M.H. and Eckenrode C.J. (1975). Variation in *Brassica oleracea* resistance to cabbage looper and imported cabbageworm in the greenhouse and field. *J. Econ. Entomol.*, 68. 757-760.

Dosdall, L.M. (1994). Evidence for successful overwintering of diamondback moth, *Plutella xylostella* (L.) (Lepidoptera:Plutellidae), in Alberta. *Can. Entomol.,* 126:183-185.

Dosdall, L.M., Mason, P.G., Olfert, O., Kaminski, L. and Keddie, B.A. (2004). The origins of infestations of diamondback moth, *Plutella xylostella* (L.), in canola in Western Canada. Management of diamondback moth and other crucifer pests. *Proc. IV Interntl. Workshop.* 95-100*pp*

Eigenbrode, S.D. and Shelton, A.M. (1992). Resistance to diamondback moth in *Brassica*: mechanisms and potential for resistant cultivars. In Diamondback moth and other crucifer pests: *Proc. 2nd Interntl. Workshop*, Asian Vegetable Research and Development Centre Tainan, *Shanhua* Taiwan, December, 1990. 65-74*pp*

Eigenbrode, S.D., Espelie, K.E. and Shelton, A.M. (1991b). Behavior of neonate diamondback moth larvae (*Plutella xylostella* [L.]) on leaves and on extracted leaf waxes of resistant and susceptible cabbages. *J. Chem. Ecol.,* 17:1691-1704.

Eigenbrode, S.D., Stoner, K.A., Shelton, A.M. and Kain, W.C. (1991a). Characteristics of glossy leaf waxes associated with resistance to diamondback moth (Lepidoptera:Plutellidae) in *Brassica oleracea* L. *J. Econ. Entomol.,* 84:1609-1618.

Elahi, K.M. (2008) Social forestry, exotic trees and monga. The Daily Star Published 6 Sept 2008. *URL: http://www.thedailystar.net/story.phpnid=53438* (accessed on 6 Sept. 2008)

Endersby, N., Weeks, A., Mckechnie, S., Ridland, P. and Edwards, J. (2003). Development of genetic markers to study dispersal of diamondback moth, *Plutella xylostella* (L.) in Australia. *13th Biennial Aust. Res. Ass. on Brassica. Proc. Conf.* Tamworth, New South Wales, Australia, 58-61. *Entomol. Exptl. Appl.,* 42(3):243-247.

Enkegaard, A. (1993). The poinsettia strain of the cotton whitefly, *Bemisia tabaci* (Homoptera:Aleyrodidae), biological and demographic parameters on poinsettia (*Euphorbia pulcherrima)* in relation to temperature. *Bull. Entomol. Res.,* 83:535-546.

Facknath S. (1997) Integrated pest management of *Plutella xylostella*, an important pest of crucifers in Mauritius. *Food Agric. Res. Co.* Réduit, Mauritius, 103-108*pp*

Feeny, P. (1976). Plant apparency and chemical defense. *Rec. Adv. Phytochem.*, 10:1-40.

Finch, S. (1996).Appropriate/inappropriate landings, a mechanism for describing how under sowing with clover affects host-plant selection by pest insects of *Brassica* crops. *IOBC/WPRS Bull.*, 19(11):102-106.

Finch, S. and Kienegger, M. (1997). A behavioural study to help clarify how under sowing with clover affects host plant selection by pest insects of *Brassica* crops. *Entomol. Exptl. Appl.*, 84:165-172.

Fletcher, T.B. (1914). Some South Indian Insects. *Superintd. Govt. Press*, Madras. *Acad. Sci., USA*, 88: 5119–5123.

Garcia, R.J.L. (1991). Seasonal variation of the cabbage moth Diamondback moth, *Plutella xylostella* L. (Lepidoptera:Yponomeutidae) and of the larval parasitoid *Diadegma insulare* Cresson (Hymenoptera:Ichneumonidae), in the Cataurito Experimental station, Aragua State. *Bol. Entomol.Venezolana.* 6(1): 27-35.

Gautam, R.C. (1995). Intercropping in pearl millet: a remunerative practice of rainfaii farming. *Ind. Farming*, July:21-22.

Gera, S.S., and Bhatnagar, K.N. (1992). Seasonal incidence of pest complex of cabbage and their control in semi-arid region. *Pestology,* 16:38-45.

Gibson, R.W. and Pikett, J.E. (1983). Wild potato repels arthropods by release of aphid alarm pheromone. *Nature,* 302:608-609.

Golizadeh, A., Kamali, K., Fathipour, Y. and Abbasipour, H. (2007). Temperature dependent development of diamondback moth, *Plutella xylostella* (Lepidoptera:Plutellidae) on two brassicaceous host plants. *Insect Sci.,* 14:309-316.

Golizadeh, A., Kamali, K., Fathipour, Y. and Abbasipour, H. (2009). Effect of temperature on life table parameters of *Plutella xylostella* (Lepidoptera:Plutellidae) on two Brassicaceous host plants. *J. Asia-pacific Entomol.* 12:207-212.

Gonzalez-Rodriguez, A.L., and Macchiavelli, R. (2003). Dynamics of diamondback moth, *Plutella xylostella* L. (Lepidoptera:Plutellidae) in cabbage under intercropping, biological control and *Bt.*-based sprays. *J. Univ. Puerto Rico.* 87(1/2):31-49.

GuoQuan, Yu., Wei Jian, Wu., DeJiu, Gu., WeiQiu, Z., G.Q., Y., W.J., W., D.J., G. and Zhang, W.Q. (1998). Preliminary studies on oviposition preference to host plants of diamondback moth, *Plutella xylostella* and its application. *J. South China Agric. Univ.,* 19(1):61-64.

Gupta, P.D. and Thorsteinson, A.J. (1960). Food plant relationships of the diamondback moth (*Pluetlla maculipennis* (Curt.). II Sensory regulation of oviposition of the adult female. *Entomol. Exptl. Appl.,* 3:305-314.

Hama, H. (1986). Resistance spectrum to various insecticides in the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera:Yponomeutidae). *Jap. J. Appl. Entomol. Zool.,* 30(4):277-284.

Hamilton, A.J., Endersby, N.M., Ridland, P.M., Zhang, J. and Neal, M. (2005). Effects of cultivar on oviposition preference, larval feeding and development time of diamondback moth, *Plutella xylostella* (L.) (Lepidoptera:Plutellidae), on some *Brassica oleracea* vegetables in Victoria. *Aust. J. Entomol.,* 44(3):284-287.

Hance, T., Nibelle, D., Lebrun, P., Van Impe, G., Van Hove, C. (1994). Selection of Azolla forms resistant to the water lily aphid, *Rhopalosiphum nymphaeae*. Life history of *Rhopalosiphum nymphaeae*. *Entomol. Exptl. Appl.,* 70:11-17.

Harcourt DG. (1960). Biology of the diamondback moth, *Plutella maculipennis* (Curt.) (Lepidoptera:Plutellidae) in eastern Ontario. III. Natural enemies. *Can. Entomol.,* 92:419-428.

Harcourt, D.G. (1954). The Biology and ecology of the diamondback moth, *Plutella maculipennis* (Curt.) in Eastern Ontario. Ph.D. thesis. Cornell Univ., Ithaca, NY 107*pp*

Harcourt, D.G. (1957). Biology of the diamondback moth, *Plutella maculipennis* (Curt.) (Lepidoptera: Plutellidae) in Eastern Ontario. II. Life-history, behaviour, and host relationships. *Can. Entomol.,* 89:554-564.

Harcourt, D.G. (1962). Biology of cabbage caterpillars in Eastern Ontario. *Proc. Entomol. Soc. Ont.,* 93:61-75.

Harcourt, D.G. (1963). Major mortality factors in the population dynamics of the diamondback moth, *Plutella maculipennis* (Curt.) (Lepidoptera:Plutellidae). *Mem. Entomol. Soc. Can.,* 32:55-56.

Harcourt, D.G. (1969). The development and use of life tables in the study of natural insect populations. *Ann. Rev. Entomol.,* 14:175-196.

Harcourt, D.G. (1986). Population dynamics of the diamondback moth in Southern Ontario. In N. S. Talekar (ed.), Management of Diamondback Moth and other Crucifer Pests: *Proc. I Interntl. Workshop,* A.V.R.D.C., Tainan, Taiwan, 11-15 March, 19(8):3-15*pp*

Harcourt, D.G. 1969. The development and use of life tables in the study of natural insect populations. *Ann. Rev. Entomol.,* 14:175-196.

Hardie, J., Gibson, G. and Wyatt, T.D. (2001). Insect behaviours associated with resource finding. In Insect Movement, Mechanisms and Consequences. *CABI Publ.,* Wallingford, Oxford. 87-109*pp*

Hardy, J.E. (1938). *Plutella maculipennis* Curt. Its natural and biological control in England. *Bull. Entomol. Res.,* 29:343-72.

He, Y.R., Lu, L.H. and Pang, X.F. (2000). Costruction and analysis of the natural population life table for continuous generation of the diamondback moth , *Plutella xylostella* L. *J. South China Agric. Univ,,* 21(1):34-37.

Hemchandra, O. and Singh, T.K. (2003) Life table, rate of increase and stable-age distribution of *Plutella xylostella* (Linn.) on cauliflower. *Ann. Pt. Protec. Sci.,* 11(2):269-273.

Hemchandra, O. and Singh, T.K. (2004). Life table, rate of increase and stable-age distribution of *Plutella xylostella* (Linn.) on knol khol. *U.P. J. Zool.,* 24(2):161-167.

Hemchandra, O. and. Singh T.K (2005). Life table , stable age distribution and life expectancy of *Plutella xylostella on Brassica juncea. Ann. Pl. Protec. Sci.* 13:302-306.

Hemchandra, O., and Singh, T.K. (2007). Population dynamics of DBM, *Plutella xylostella* L. on cabbage agroecosystem in Manipur. *Ind. J. Entomol.,* 69(2):154-161.

Hillyer, R.J. and Thorsteinson, A.J. (1969). The influence of host plant or males on ovarian development or oviposition in the diamondback moth, *Plutella maculipennis* (Curt.). *Can. J. Zool.,* 47:805–816.

Ho, T.H. (1965). The life-history and control of the diamondback moth in Malaya. *Bull. No.* 118, Div. Agric., 26*pp*

Hokkanen, H.M. (1991). Trap cropping in pest management. *Ann. Rev. Entomol.,* 36:119-138.

Hopkins, R.J. and Ekbom, B. (1999). The pollen beetle, *Meligethes aeneus* changes egg production rate to match host quality. *Oecologia,* 120:274–278.

Howe, R. W. (1953). The rapid determination of the intrinsic rate of increase of an insect population. *Ann. Appl. Biol.,* 40:134-155.

Hughes, P.R., Renwick, J.A.A. and Lopez, K.D. (1997). New oviposition stimulants for the diamondback moth in cabbage. *Entomol. Exptl. Appl.* 85:281-283.

Idris, A.B. and Grafius, E. (1996). Effects of wild and cultivated host plants on oviposition, survival, and development of diamondback moth (Lepidoptera:Plutellidae) and its parasitoid, *Diadegma insulare* (Hymenoptera: Ichneumonidae). *Environ. Entomol.,* 25:825–833.

Iga, M. (1985). The seasonal prevalence of occurrence and the life tables of the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera:Yponomeutidae). *Jap. J. Appl. Entomol. Zool.,* 29:119-125.

Janarti, P.L. (1982). Monitoring of parasites and predators of cabbage pests on cabbage communities treated with insecticides (in Indonesia). *Ph. D. Thesis,* Department of Biology, Bandung Institute of technology, Bandung West Java Indonesia, 65 *pp*

Javaid, I., Saifudine, N., Tombolane, L., and Rafael, E. (2000). Efficacy of aqueous neem extracts in the control of diamondback moth, *Plutella xylostella* (L.) on cabbage. *Insect Sci. Appl.* 20(2):167-170.

Javier, E.Q. (1992). Foreword in diamondback moth and other crucifer pests. In N. S. Talekar (ed.), Management of diamondback moth and other crucifer pests: *Proc. II Interntl. Workshop,* A.V.R.D.C., Shanhua, Taiwan, 447-454*pp*

Jayaraj, S., Bharathi, M. and Sundra Babu, P. C. (1993). Integrated pest management. In Randhawa, N. S. and Parmar, B. (eds) "Neem Research and Development" *SPS Pub.No.3 Soc. Pesticide Sci.,* India. 154-167 *pp*

Jayarathnam, K. (1977). Studies on the population dynamics of the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae) and crop loss due to the pest in cabbage. *Ph. D. thesis.* Univ. Agric. Sci. Bangalore, India, 215*pp*

Jeffree, C.E., Baker, E.A., Hollowary, P.J. (1976). Origins of the five structure of plant epicuticular waxes. In Dickson, C.H. and Preece, T.F. (eds.) "Microbiology of Aerial Plant Surfaces", *Acad Press* London, 119-158 *pp*

Jiang, L.H., Wang, D. and Liu, S.S. (2001) Effects of plant on the oviposition preference of *Plutella xylostella* and host-selection behaviour of *Cotesia plutellae. J. Zhejiang Univ. Agric. Life Sci.,* 27:273–276.

Johnson, D.R. (1953). *Plutella maculipennis* resistance to DDT in Java. *J. Econ. Entomol.,* 6:176.

Jolliffe, P.A. (1997). Are mixed populations of plant species more productive than pure stands. *Oikos,* 80:595-602.

Joshi, B. G., Ramaprasad, G. and Sitaramaiah, S. (1982). Effect of neem seed kernel suspention on *Telenomous remus,* an egg parasite of *Spodoptera litura, Phytoparasit.,* 10:61-63.

Justin, C.G.L., Kumar, M.G. and Swamiappan, M. (2001). Life table studies of the diamondback moth *Plutella xylostella* (L.) on cauliflower, cabbage and mustard. *Madras. Agric. J.,* 87:206-210.

Justus, K.A., Dosdall, L.M. and Mitchell, B.K. (2000). Oviposition by *Plutella xylostella* (Lepidoptera:Plutellidae) effects of *Phylloplane waxiness. J. Econ. Entomol.,* 93(4):1152-1159.

Kahuthia-Gathu, R., Lohr, B. and Poehling, H.M. (2008). Development and reproductive potential of diamondback moth, *Plutella xylostella* (Lepidoptera:Plutellidae) on cultivated and wild crucifer spp. in Kenya. *Interntl. J. Trop. Insect. Sci.,* 28(1):19-29.

Kandoria, J.L., Lal, A. and Singh, I. (1996). New record of a parasitoid, *Cotesia plutellae* (Kurdj.) of *Plutella xylostella* (Linn.) from Punjab. *J. Insect Sci.,* 9:80.

Kandoria, J.L., Lal, A., Labh, S. and Singh, L. (1994). Biology of diamondback moth, *Plutella xylostella* (L.) on cauliflower. *J. Insect Sci.,* 7(1):76-80.

Kandoria, J.L., Singh, G. and Singh, L. (1999). Effect of intercropping cauliflower with tomato on the incidence of diamondback moth. *Insect Environ.,* 5(3):137-138.

Karel, A. K., Lakhani, D. A. and Ndunguru, B. J. (1982). Intercropping of maize and cowpea: Effect of plant populations on insect pest and seed yield. In Keswani, C. L. and Ndunguru, B. J. (eds) Intercropping: *Proc. 2nd Symp. Intercropping in Semi-Arid Areas,* at Morogoro, Tanzania, 4-7 August, 1980. International Development Research Centre, Ottawa, Canada, 102-109*pp*

Keinmeesuke, P., Vattanatangum, A., Sarnthoy, O., Sayampol, B., Miyata, T., Saito, T., Nakasuji, F. and Sinchaisri, N. (1991). Life table of diamondback moth and its egg parasites, *Trichogrammatoidea bactrae* in Thailand. In N. S. Talekar (ed.), Management of diamondback moth and other crucifer pests: *Proc. 2nd Internatl. Workshop,* A.V.R.D.C., Shanhua, Taiwan, 309-315*pp*

Kfir, R. (2002). Biological control of the diamondback moth, *Plutella xylostella* in Africa. *Interntl. Symp. Improving Bio-control of Plutella xylostella.* Monterpiller, France, 21-24 October.

Khan, M.F.R., Griffin, R.P., Carner, G.R. and Gorsuch, C.S. (2004). Diamondback moth (Lepidoptera: Plutellidae) Population density and parasitism by *Diadegma insulare* on collard in South Carolina. *J. Agric. Urban Entomol.,* 21(3):164-170.

Khan, Z.R., Ampong-Nyarko, K., Chilishwa, P., Hassanali, A., Kimani, S., Lwande, W., Overholt, W.A., Pickett, J.A., Smart, L.E., Wadhams, L.J. and Woodcock, C.M. (1997). Intercropping increases parasitism of pests. *Nature* (London) 388:631–632.

Khan. H.K., Nagraj, G.N., and Reddy, S.Y.S. (1991). Integrated Pest Management Demonstrations in cabbage. *Pl. Protec. Bull.* Faridabad. 43(3-4):11-12.

Kibata, G.N. (1996). The diamondback moth a problem pest of *Brassica* crops in Kenya. Management of diamondback moth and other crucifer pests. *Proc. III Interntl. Workshop.,* Kuala Lumpur, Malaysia, 47–53*pp*

Klemola, T., Ruohomäki, K., Tanhuanpaa, M. and Kaitaniemi, P. (2003). Performance of a spring-feeding moth in relation to time of oviposition and bud-burst phenology of different host species. *Ecol. Entomol.,* 28:319–327.

Koshihara, T. (1986). Diamondback Moth and its Control in Japan. *In:* Talekar, N. S., and Griggs, T. G. (eds.) Diamondback Moth Management and other Crucifer pests: *Proc. Ist Interntl. Workshop,* A.V.R.D.C.,Shanhua, Taiwan. 43-53*pp*

Krishnakumar, Srinivasan, K. K., Ramachander, P.K. and Suman, C.L. (1984). Optimum control strategy of cabbage pests from a chemical control trial. *Singapore J. Prim. Ind. Bull.,* 25 (2):85-87.

Krishnamoorthy, A. (2002). Biological control of diamondback moth *Plutella xylostella* (L.), an Indian scenario with reference to past and future strategies. In: Kirk, A.A., Bordat, D. (eds.), *Proc. Interntl. Symp.* 21–24 October, 2002, Montpellier, France, C.I.R.A.D., 204-211*pp*

Krishnamoorthy, A., Rama, N., Mani, M., and Pattar, G.L. (2002). Biological control of diamondback moth, *Plutella xylostella* (Linnaeus). In cabbage integrating egg parasitoid *Trichogrammatoidea bactrae* Nagaraja with trap crop. *Biol. Cont. Lepidop. Pests.* July 17-18, Banglore, India, 275-278*pp*

Kulye, M.S., Gondhalekar, A.D., Chaudhari. C.S., and Chandele, A.G. (2007). Efficacy of some moult inhibiting insecticides against *Plutella xylostella* on cabbage. *Ann. Pl. Protec. Sci.* 15(2):469-470.

Kumar, G.V.S., and Sannaveerapanavar, V.T. (2004). Evaluation and bio-efficacy of insecticide and seed oil combinations against *Plutella xylostella* L. (Lepidoptera:Yponomeutidae) on cabbage. *Mysore J. Agric. Sci.* 38(3):302-305.

Kumar, P., Prasad, C. S., and Patel, L. (2007). Efficacy and economics of insecticides and biopesticides against *Plutella xylostella* on cabbage. *Ann. Pl. Protec. Sci.* 15:342-344.

Kuno, E. (1991). Sampling and analysis of insect populations. *Ann. Rev. Entomol.,* 36:285-304.

Kuwahara, M., Keinmeesuke, P. and Shirai, Y. (1995). Seasonal trend in population density and adult body size of the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), in central Thailand. *Appl. Entomol. Zool.,* 30:551–555.

Ladd, T.L., Jacobson, M. and Buriff, C.R. (1978). Japancese beetles: Extracts from neem tree seeds as feeding deterrents. *J. Econ. Entomol.* 71:810-813.

Lal, O.P., and Meena, R.K. (2001). Effects of certain insecticides against diamondback moth, *Plutella xylostella* (L.) on cabbage under field condition. *Pest. Res. J.*, 13(2):242-246.

Lin, J., Dickson, M.H. and Eckenrode, C.J. (1984). Resistance of *Brassica* lines to the diamondback moth (Lepidoptera: Yponomeutidae) in the field and inheritance of resistance. *J. Econ. Entomol.* 77:1293–1296.

Lin, J., Eckenrode, C.J. and Dickson, M.H. (1983). Variation in *Brassica oleracea* resistance to diamondback moth (Lepidoptera: Plutellidae). *J. Econ. Entomol.*, 76:1423-1427.

Lingappa,S.,Basavanagoud,K., Kulkarni,K. A., Roopa, S.P. and Kambrekar, D.N. (2000). Threat to Vegetable Production by Diamondback Moth and its management Strategies. *In*: *IPM Syst. Agric.*, 235-248*pp*

Liu, S.S., Chen, F.Z. and Zalucki, M.P. (2002). Development and survival of the diamondback moth (Lepidoptera:Plutellidae) at constant and alternating temperatures. *Environ. Entomol.*, 31(2):221-231.

Liu, H., Chi, H., Chen, C.N. and Kung, K.S. (1985). The population parameters of the diamondback moth, *Plutella xylostella* (L.) on common kale. *Pl. Protec. Bull. Taiwan.*, 27(2):145-153.

Lotka, A.J. (1925). Elements of Mathematical Biology. *Dover*, New York.

Lu, F.M. and Lee, H.S. (1984). Observation of the life history of diamondback moth, *Plutella xylostella* (L.) in whole year. *J. Agric. Res. China*, 33:424-30.

Lu, J.H., Liu, S.S. and Shelton, A.M. (2004). Laboratory evaluation of a wild crucifer *Barbarea vulgaris* as a management tool for the diamondback moth, *Plutella xylostella* (Lepidoptera: Plutelldae). *Bull. Entomol. Res.* 94:509-516.

Luther, G.C., Valenzuela, H.R. and Defrank, J. (1996). Impact of cruciferous trap crops on lepidopteran pests of cabbage in Hawaii. *J. Econ. Entomol.*, 25:39–47.

Madder, D.J. and Stemeroff, M. (1988). The economics of insect control on wheat, corn and canola, 1980–1985. *Bull. Entomol. Soc. Can.*, 20-22*pp*

Martinez, S. S. and Van Emden, H. F. (1999). Sublethal concentrations of azadirachtin affect food intake, conversion efficiency and feeding behaviour of *Spodoptera littoralis* (Lepidoptera: Noctuidae). *Bull. Entomol. Res.*, 89:65-71.

Meena, R.K. and Lal, O.P. (2002). Effect of intercropping on incidence of diamondback moth, *Plutella xylostella* (L) on cabbage. *J. Entomol. Res.*, 26(2):141-144.

Mohan, M. and Gujar, G.T. (2002). Geographical variation in susceptibility of the diamondback moth, *Plutella xylostella* L. (Lepidoptera:Plutellidae) to *Bacillus thuringiensis* strains and purified toxins and associated resistant development in India. *Bull. Entomol. Res.*, 92:489-498.

Mohan, M. and Gujar, G.T. (2003). Local variation in susceptibility of the diamondback moth, *Plutella xylostella* (L.) to insecticides and detoxification enzymes. *Crop Protec.*, 22:495–504.

Monks, A. and Kelly, Dave (2003). Motivation models fail to explain oviposition behavior in the diamondback moth. *Physiol. Entomol.*, 28:199–208.

Moorthy, P.N.K. and Kumar, N.K.K. (2000). Efficacy of neem seed kernel powder extracts on cabbage pests. *Pest Managt. Hortic. Ecosys.* 6(1):27-31.

Morris, R.F. (1963). The dynamics of epidemic spruce budworm populations. *Mem. Entomol. Soc. Can.*, 31:1–332.

Morris, R.F. and Miller, C.A. (1954). The development of life tables for the spruce bud worm. *Can. J. Zool.*, 32:283-301.

Mosiane, S.M., Kfir, R. and Villet, M.H. (2003). Seasonal phenology of the diamondback moth, *Plutella xylostella* (L.), (Lepidoptera:Plutellidae) and its parasitoids on canola, *Brassica napus* (L.), in Gauteng province, South Africa. *African Entomol.,* 11(2):277–285.

Mulik, A.P., Borikar, P.S. and Waghmare, U.M. (2000). Population dynamics of *Brevicoryne brassicae* L. and *Plutella xylostella* L. on cauliflower (*Brassica oleracea* var. *botrytis.*) *Pestology.* XXIV(7):48-50.

Murthy, M.S., Jagdish, P.S., and Sannaveerappanvar, V.T. (2006). Efficacy of plant products and new insecticides against diamondback moth, *Plutella xylostella* L. (Lepidoptera: Yponomeutidae) on cabbage. *J. Pl. Protec. Envior.* 3(2):1-5.

Musser, F.R., Nault, B.A., Nyrop, J.P. and Shelton, A.M. (2005). Impact of glossy collard trap crop on diamondback moth adult movement, oviposition and larval survival. *Entomol. Exptl. Appl.,*.117:71-78.

Nagarkatti, S. and Jayanth, K.P. (1982). Population dynamics of major insect pests of cabbage and of their natural enemies in Bangalore district (India) *In: Proc. Interntl. Conf. Pl. Protec. Tropics. Malaysian Pl. Protec. Soc. Malaysia,* 325-347*pp*

Nagesh, M., and Verma, S. (1997). Bioefficasy of certain insecticides against diamondback moth (*Plutella xylostella*) on cabbage. *Ind. J. Entomol.* 59(4):411-414.

Nathu-Ram., Raju, S.V.S., Singh, H.N. (2000).Varietal resistance of different cabbage varieties/entries against *Plutella xylostella* under field conditions. *Ind. J. Entomol.,* 62(2): 175-180.

Navatha, S. and Murthy, K.S. (2006). Host preference for oviposition and feeding by diamondback moth, *Plutella xylostella* (L.). *Ann. Pt. Protec. Sci.,* 14(2):283-286.

Nofemela, R.S., and Kfir, R. (2005). The role of parasitoid in suppressing diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae) population on unsprayed cabbage in the North West Province of South Africa. *African Entomol.* 13(1):71-83.

Omar, D. and Mamat, M.J. (1997). The feasibility of using sterile insect technique for the control of diamondback moth on cabbage in Cameron Highlands. *Proc. III Interntl. Workshop,* Kuala Lumpur, Malaysia, 130-133*pp*

Ooi, P.A.C. and Sudderuddin, K.I. (1978). Control of diamondback moth in Cameron Highlands, Malaysia. *Proc. Pt. Protec. Conf., Rubber Res. Instt.* Malaysia, Kuala Lumpur, 214-227*pp*

Palaniswamy, P.C., Gillot, C., Slater, G.P. (1986). Attraction of diamondback moth, *Plutella xylostella* (L.) (Lepidoptera:Plutellidae), by volatile compounds of canola, white mustard and faba bean. *Can. Entomol.,* 118:1279–1285.

Panse, V.G., and Sukhatme, P.V. (1985). *Statistical Methods for Agricultural Research,* I.C.A.R., New Delhi.

Papaj, D.R. (2000). Ovarian dynamics and host use. *Ann. Rev. Entomol.,* 45:423–448.

Park, T.S., Koh, S.J., Lim, S.O., Hyon, S.W. and Song, C.H. (1993). Studies on ecological characteristics of the diamondback moth, *Plutella xylostella* (L.) in Cheju Island. *R.D.A. J. Agric. Sci. Crop Protec.,* 35(2):364- 370.

Parmar, B. S. (1993). Scope of botanical pesticide in integrated pest management. *J. Insect Sci.,* 6(1):15-20.

Patel, J.J., Patel, N.C., Jayani, D.B., Patel, J.R. (1996). Bioefficacy of synthetic and botanical insecticides against aphid, *Lipaphys erysimi* Kalt and diamondback moth, *Plutella xylostella* L. infesting cabbage. *Guj. Agri. Univ. Res. J.* 22(1):67-71.

Patil, S.P., and Pokharkar,R.P. (1971). Diamondback moth, a serious pest of crucifers. *Res. J. Mahatma Phule Agric. Univ.,* 2:134-139.

Perez, C.J., Alvarado, P., Narvaez, C., Miranda, F., Hernandez, L., Vanegas, H., Hruska, A. and Shelton, A.M. (2000). Assessment of insecticide resistance in five insect pests attacking field and vegetable crops in Nicaragua. *J. Econ. Entomol.,* 93:1779–1787.

Pivnick, K.A. Jarvis, B.J., Gillott, C., Slater, G.P. and Underhill, E.W. (1990). Daily patterns of reproductive activity and the influence of adult density and exposure to host plants on reproduction in the diamondback moth, *Plutella xylostella* (Lepidoptera:Plutellidae). *Environ. Entomol.,* 19:587–593.

Poelking, A. (1992). Diamondback moth in Philippines and its Control with *Diadegma* relationships. *Can. Entomol.,* 89:554-564.

Pramanic, P., and Chatterjee, M. L. (2004). Effect of novaleeron on the population of *Plutella xylostella* and *spodoptera litura* on cabbage. *Ann. Pl. Protec. Sci.* 12:204-205.

Prasad, S.K. (2003). Studies on population dynamics of mustard aphid, *Lipaphis erysimi* on mustard in relation to some meteorological factors. *Ind. J. Entomol.,* 65(4):569-578.

Rai, M. and Pandey, A.K. (2007). Towards a rainbow revolution. *The Hindu Survey Ind. Agric.,* 112-120*pp*

Raju, S.V.S., Chaudhary, M.K. and Singh, H.N. (1994). Bio-efficacy of some commonly used insecticides against *Plutella xylostella* Linn. *Ind. J. Entomol.* , 56(3):246-250.

Ram, N. and Singh, S.V.S. (2000). Varietal resistance of different cabbage varieties against DBM under field conditions. *Ind. J. Entomol.,* 62 (2):175-180.

Ram, N., Raju, S.V.S., and Singh, H.N. (2001). Bioefficacy of some conventional and eco-friendly insecticides against diamondback moth, *Plutella xylostella* on cabbage. *Ind. J. Entomol.* 63(4): 429-434.

Raupp, M.J., Werren, J.H. and Sadof C.S. (1988). Effects of short-term phenological changes in leaf suitability on the survivorship, growth, and development of gypsy moth (Lepidoptera: Lymantriidae) larvae. *Environ. Entomol.,* 17:316–319.

Razek, A.S., and Gowen, S. (2002). The integrated effect of the nematode-bacteria complex and neem plant extracts against diamondback moth, *Plutella xylostella* on cabbage. *Arch. Phytopathol. Pl. Protec.,* 35(3):181-188.

Reddy, C.N. and Singh, T.V.K. (1998). Life table studies of diamondback moth on cabbage at Hyderabad. *Ind. J. Entomol.,* 60(4):321-325.

Reddy, G.V.P. and Guerrero, A. (2000). Behavioural responses of diamondback moth, *Plutella xylostella,* to green leaf volatiles of *Brassica oleracea* subsp. *capitata. J. Agric. Food Chem.,* 48:6025–6029.

Reddy, G.V.P., Tabone, E. and Smith, M.T. (2004). Mediation of host selection and oviposition behaviour of the diamondback moth, *Plutella xylostella* and its predator, *Chrysoperla carnea* by chemical cues from Cole crops. *Biol. Cont.,* 29:270–277.

Reed, D.W., Pivnick, K.A. and Underhill, E.W. (1989). Identification of Chemical oviposition stimulants for the diamondback moth, *Plutella xylostella* present in three species of Brassicaceae. *Entomol. Exptl. Appl.,* 53(3):277-286.

Rembold, H., Sharma, G.K., Czoppelt, Ch. and Schmutterer, H. (1980). Evidence of growth disruption in insects without feeding inhibition by neem fractions. *J. Plant Disease Protec.* 87:290 – 297.

Renwick, J.A.A. (1989). Chemical ecology of oviposition in phytophagous insects. *Experientia,* 45: 223–228.

Renwick, J.A.A. (2002). The chemical world of crucivores: lures, treats and traps. *Entomol. Exptl. Appl.* 104:35–42.

Renwick, J.A.A. and Radke, C.D. (1990). Plant constituents mediating oviposition by the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera:Plutellidae). *Phytophaga*, 3:37-46.

Risch, S.J. (1981). Insect herbivore abundance in tropical monocultures and polycultures: an experimental test of two hypotheses. *Ecol.*, 62:1325-40.

Risch, S.J., Andow, D. and Altieri, M.A. (1983). Agro ecosystem diversity and pest control: data, tentative conclusions, and new research directions. *Environ. Entomol.*, 12:625-629.

Rodrigues, D. and Pires-Moreira, G.R. (1999). Feeding preferences of *Heliconius erato* (Lep.-Nymphalidae) in relation to leaf age and consequences for larval performance. *J. Lep. Soc.*, 53:108–113.

Root, R.B. (1973). Organization of a plant arthropod association in simple and diverse habitats: the fauna of collards (*Brassica oleracea*). *Ecol. Monogr*, 43:94-125.

Rossner, J. and Zebitz, C.P.W. (1986). Effect of soil treatment with neem products on earthworms (Lumbricidae). *Proc. 3rd Interntl Neem Conf.*, 1986, Nairobi, 627-632*pp*

Ruscoe, C. N. E. (1972). Growth disruption effect of an insect antifeedant. *Nature. New Biol.* 236: 159-160.

Sachan, J.N. and Gangwar, S.K. (1980). Vertical distribution of important pests of Cole crops in Meghalaya as influenced by the environmental factors. *Ind. J. Entomol.*, 42:414-421.

Sachan, J.N. and Srivastava, B.P. (1972). Studies on seasonal incidence of insect pests of cabbage. *Ind. J. Entomol.*, 34:123-129.

Sachan, J.N., and Gangwar, S.K. (1990). Seasonal incidence of insect pests of cabbage, cauliflower and knolkhol. *Ind. J. Entomol.*, 52(2):111-124.

Saeed, R., Sayyed, A. H., Shad, S. A. and Zaka, S. M. (2010). Effect of different host plants on the fitness of diamondback moth, *Plutella xylostella* (Lepidoptera:Yponomeutidae). *Crop Protec.*, 29:178-182.

Saito, O., Mizushima, S., Okuyama, S., Hanada, T., Torikura, H., Hachiya, K. and Sato, K. (1998). Biology of the diamondback moth, *Plutella xylostella* (L.), in Hokkaido. *Res. Bull. Hokkaido Natl. Agric. Exptl. St.*, 167:69-110.

Sanaveerappanavar, V.T., and Viraktamath, C.A. (1997). Management of insecticides resistant Diamondback moth, *Plutella xylostella* L. (Lepidoptera:Yponomeutidae) on cabbage using some novel insecticides. *Mys. J. Agric. Sci.* 31(3):230-235.

Sarfraz, M., Dosdall, L.M. and Keddie, B.A. (2005). Evidence for behavioural resistance by the diamondback moth, *Plutella xylostella* (L.). *J. Appl. Entomol.*, 129(6):340-341.

Sarfaraz, M., Dosdall, L.M. and Keddie, B.A. (2007). Resistance of some cultivated Brassicaceae to infestations by *Plutella xylostella* (Lepidoptera: Plutellidae). *J. Econ. Entomol.*, 100:215-224.

Sarnthoy, O., Keinmeesuke, P., Sinchaisri, N. and Nakasuji, F. (1989). Development and reproductive rate of the diamondback moth, *Plutella xylostella* from Thailand. *Appl. Entomol. Zool.*, 24(2):202-208.

Satpathy, S., Kumar, A., Shivalingaswamy, T.M., and Rai, M. (2007). Evaluation of new molecules for Diamondback moth management on cabbage. *Ind. J. Hortic.* 64(2):175-177.

Saxena, J.D., Rai, S., Srivastava, K.M. and Sinha, S.R. (1989). Resistance in the field population of diamondback moth to some commonly used synthetic pyrethroids *Ind. J. Entomol.*, 51(3): 265-268.

Saxena, R. C. (1989). Insecticide from neem tree. *In: Insecticide of plant origin,* ACS Symposium Series. Ed. Comstock, M. Joan. *Am. Chem. Soc.*, Washington D.C.

Sayyed, A.H., Gatsi, R., Kouskoura, T., Wright, D.J. and Crickmore, N. (2001). Susceptibility of a field-derived, *Bacillus thuringiensis*-resistant strain of diamondback moth to *in-vitro-activated Cry1Ac toxin. Appl. Environ. Microbiol.*, 67:4372-4373.

Sayyed, A.H., Omar, D. and Wright, D.J. (2004). Genetics of spinosad resistance in a multi-resistant field selected population of *Plutella xylostella. Pest Managt. Sci.*, 60:827-832.

Schmutterer, H. (1990). Properties and potential of natural pesticides from the neem tree, *Azadirachta indica. Ann. Rev. Entomol.* 35:271-297.

Schmutterer, H. and Holst, H.(1987). On the effects of the enriched and formulated neem seed kernel extract AZT-VR-K on Apis mellifera L. *J. Appl. Entomol.*, 103:208-213.

Schmutterer, H. and Rembold, H. (1980). Zur wirkung einiger Reinfraktianen aus samon von *Azadirachta indica* auf FraBaktivital und Metamorphose von *Epilachna varivestis* (Coleoptera:Coccinellidae). *Z. ang Entomol.*, 89:179-188.

Shankar, U., Bar, U.K. and Raju, S.V.S. (2005). Impact of intercropping in cauliflower on diamondback moth, *Plutella xylostella* (L.) *Ind. J. Pt. Protec.*, 33(1):43-47.

Sharma, K.C., Deepika, S. and Sharma, D. (1999). Insect pests of exotic vegetables in Himachal Pradesh. *Insect Environ.*, 5(3):18-119.

Shashidhar, V., Shekarappa, Reddy, B.S. and Patil, M.G. (1994). Effect of date of planting on the extent of damage by the diamondback moth, *Plutella xylostella* on cabbage. *Karnataka J. Agric. Sci.*, 7(2):238-239.

Shelton, A.M. (2001). Regional outbreaks of diamondback moth due to movement of contaminated plants and favourable climatic conditions. *Proc. IV Interntl. Workshop.* Management of Diamondback Moth and other Crucifer Pests. Melbourne, 26-29 Nov., 2001.

Shelton, A.M. (2004). Management of the diamondback moth de ja`vu all over again. *Proc. IV Interntl. Workshop,* Management of Diamondback Moth and other Crucifer Pests, Melbourne., 26–29 Nov., 2001.

Shelton, A.M. and Nault, B.A. (2004). Dead end trap cropping: a technique to improve management of the diamondback moth, *Plutella xylostella* (Lepidoptera:Plutellidae). *Crop Protec.*, 23:497-503.

Shelton, A.M., Sances, F.V., Hawley, J., Tang, J.D., Bourne, M., Jungers, D., Collins, H.L. and Farias, J. (2000). Assessment of insecticide resistance after the outbreak of diamondback moth in California in 1997. *J. Econ. Entomol.*, 93:931–936.

Shinoda, T., Nagao, T., Nakayama, M., Serizawa, H., Koshioka, M., Okabe, H. and Kawai, A. (2002). Identification of a triterpenoid saponin from a crucifer, *Barbarea vulgaris*, as a feeding deterrent to the diamondback moth, *Plutella xylostella. J. Chem. Ecol.*, 28:587–599.

Shirai, Y. (2000). Temperature tolerance of the diamondback moth, *Plutella xylostella* (Lepidoptera: Yponomeutidae) in the tropic and temperate regions of Asia. *Bull. Entomol. Res.*, 90:357-364.

Shukla, A., and Kumar, A. (2003). Economics of some IPM modules against diamondback moth, *Plutella xylostella* (Linn.) infesting cabbage. *Pl. Prot. Bull.* Faridabad. 55(1/2):9-13.

Shukla, A., and Kumar, A. (2003). Seasonal activity of larval parasitoid, *Cotesia plutellae* on *Plutella xylostella* in cabbage ecosystem. *J. Entomol. Res.*, 27 (3):184-184.

Shukla, A., and Kumar, A. (2004). Residual toxicity of pesticides against *Plutella xylostella* (Linn.) infesting cabbage. *Pl. Protec. Bull.* 56(1/2):11-13.

Shukla, A., and Kumar, A. (2004). Screening of cabbage varities for resistance to *Plutella xylostella* (Linn.). *U.P. J. Zool.* 24(2):169-172.

Shukla, A., and Kumar, A. (2004). Seasonal incidence of diamondback moth, *Plutella xylostella* (Linn.) in relation to abiotic factor on cabbage. *Pl. Protec. Bull.* Faridabad. 56(3/4):37-38.

Shukla, A., and Kumar, A. (2006). Seasonal activity of pupal parasitoid *Tetrastichus sokolowskii* (Kurdjumov) on *Plutella xylostella* in cabbage ecosystem. *Entomon.* 31(4):319-322.

Shukla, A., and Kumar, A. (2006). Seasonal activity of *Tetrastichus sokolowskii* (Kurdjumov) a pupal parasitoid on *Plutella xylostella* in cabbage ecosystem. *J. Entomol. Res.* 30(2):155-157.

Sidlyarevich, V., Lameko, V., Dabrowski, Z.T. and Narkiewicz, J.J. (2000). Some ecological peculiarities of the diamondback moth, *Plutella maculipennis* Curt. population development. *Proc. Interntl. Symp. Lep. Pests in Vegetables*, Skierniewice, Poland, 2-3 December, 1998. *Veg. Crops Res. Bull.*, 52:31-38.

Singh, D. and Kothari, S.K. (1997). Intercropping effects on mustard aphid, *Lipaphis erysimi* (Kalt.) population. *Crop. Sci.*, 37:1263-1264.

Singh, R. P. (1993). Neem for the management of stored grain insects in developing countries. Souvenir. World Neem Conference, *Ind. Soc. Tobacco. Sci.* Central Tobacco Research Institute, Rajamurthy (A.P.). 69-80*pp*

Singh, R.P. and Kataria, P.K. (1991). Insects, nematodes and fungi evaluated with neem (*Azadirachta indica A. Juss*) in India. *Neem Newsletter.*, 8 (1):5-11.

Sivapragasam, A., Tee, S.P. and Ruwaida, M. (1982). Effects of intercropping cabbage with tomato on the incidence of *Plutella xylostella* (L.). *MAPPS-Newsletter.* 6(2):6-7.

Sivapragassam, A., Saito, T., and Ito, Y. (1988). Marking adult Diamondback moth, *Plutella xylostella* L., and estimation of adult survival rate and population density in a cabbage field. *Appl. Entomol. Zool.* 23(3):243-250.

Southwood, T.R.E. (1978). Ecological methods with particular reference to the study of insect populations. 2nd ed. *Chapman and Hall*, London. 524*pp*

Srinivasan, K. (1984). Visual damage thresholds for diamondback moth *Plutella xylostella* (L.) and leaf webber, *Crocidolomia binotalis* Zeller on cabbage. *Ph. D. Thesis* Univ. Agric. Sci. Bangalore., 166*pp*

Srinivasan, K. and Krishnamoorthy, P.N. (1992). Development and adoption of integrated pest management for major pests of cabbage using Indian mustard as a trap crop. In N. S. Talekar (ed.), Management of Diamondback Moth and other Crucifer Pests: *Proc. II Interntl. Workshop*, A.V.R.D.C. Shanhua, Taiwan, 511-521*pp*

Srinivasan, K. and Veeresh, G.K. (1986). Economic analysis of a promising cultural practice in the control of moth pests of cabbage. *Insect Sci. Appl.*, 7(4):559-563.

Srinivasan, K., and Moorthy, P.N.K. (1991). Indian mustard as atrap crop for management of major lepidopterous pests on cabbage. *Trop. Pest Managt.*, 37(1):26-32.

Srivastav, K.A. and Parmar, B.S. (1985) Evaluation of neem oil emulsifiable concentrate against sorghum aphids. *Neem Newsletters*, 2(1):7.

Steets, R. and Schmutterer, H. (1975). Einflub van Azadirachtin auf die Lebensdauer und das Reproduktion vermogen Von *Epilachna variensis* Muls. (Coleoptera:Coccinellidae). *Z. Pflkrankh Pflschutz.*, 82:176-179.

Stoner, K.A. (1990). Glossy leaf wax and plant resistance to insects in *Brassica oleracea* under natural infestation. *Environ. Entomol.*, 19:730-739.

Stoner, K.A. (1992). Resistance and susceptibility to insect pests in glossy genetic lines of *Brassica oleracea* in Connecticut, USA. In: Proc. II Interntl. Workshop, Dec. 1990, Tainan, Taiwan, *Shanhua, Asian Vegetable Research and Development Centre*, 57-63*pp*

Sujatha, R., Rao, P. A. and Rao. K. T. (1997). Seasonal occurrence of *Crocidolomia bmotahs* Zeller and *Plutella xylostella* Linn. on mustard. *Andhra Agric. J.* 44(3 &4):41-45.

Sundaram, A. M., and Dhandapani, N. (2008). Life table of *Plutella xylostella* Linn. on cauliflower leaves treated with gibberalic acid and *Pseudomonas fluorescens* (Migula). *Ind. J. Entomol.* 70(3):241-245.

Syed, T.S. and Abro, G.H. (2003). Effect of *Brassica* vegetable hosts on biology and life table parameters of *Plutella xylostella* under laboratory conditions. *Pak. J. Biol. Sci.*, 6:1891–1896.

Tabashnik, B.E., Cushing, N.L. and Johnson, M.W. (1987). Diamondback moth (Lepidoptera:Plutellidae) resistance to insecticides in Hawaii: intra-island and cross resistance. *J. Econ. Entomol.*, 80:1091-1099.

Tabashnik, B.E., Cushing, N.L., Finson, N. and Johnson, M.W. (1990). Field development of resistance to *Bacillus thuringiensis* in diamondback moth (Lepidoptera:Plutellidae). *J. Econ. Entomol.*, 83:1671-76.

Talekar, N.S. and Lee, S.T. (1985). Seasonality of insect pests of Chinese cabbage and common cabbage in Taiwan. *Pt. Protec. Bull.* Taiwan, 27:47-52.

Talekar, N.S. and Shelton, A.M. (1993). Biology, ecology and management of the diamondback moth. *Ann. Rev. Entomol.*, 38:275-301.

Talekar, N.S., Lee, S.T. and Huang, S.W. (1986). Intercropping and modification of irrigation method for the control of diamondback moth. In N. S. Talekar (ed.), Management of Diamondback Moth and other Crucifer Pests: *Proc. I Interntl. Workshop*, Tainan, Taiwan, 11-15 March, 1985. 145-155*pp*

Talekar, N.S., Liu, S.H.,Chen, C.L., Liu, Y.,Y.F., Chen, C.L. and Yiin, Y.F. (1994). Characteristics of oviposition of diamondback moth (Lepidoptera:Yponomeutidae) on cabbage. *Zool. Studies.*, 33(1):72-77.

Talekar, N.S., Yang, J.C. and Lee, S.T. (1990). Annonated bibliography of diamondback moth, vol. 2. Shanhua, Taiwan: A.V.R.D.C.,199*pp*

Theunissen, J. and G. Schelling. (1996). Undersowing crops of white cabbage with strawberry clover and spurrey. *IOBC/WPRS Bull.*, 19(11): 128-135.

Thorsteinson, A.J. (1953). The chemotactic responses that determine host specificity in an oligophagous insect [(*Plutella maculipennis* (Curt.)] (Lepidoptera). *Can. J. Zool.*, 31: 52–72.

Timbilla, J.A. and Nyako, K.O. (2001). Efficacy of intercropping as a management tool for the control on insect pests of cabbage in Ghana. *Tropicultura,* 19(2):49-52.

Tingey, W.M. and Lamont, W.J.Jr. (1988). Insect abundance in field beans altered by intercropping. *Bull. Entomol. Res.*, 78:527-535.

Tsunoda, S. (1980). Eco-physiology of wild and cultivated forms in *Brassica* and allied genera. In *Brassica* Crops and Wild Allies: Biology and Breeding, *Jap. Sci. Soc. Press.*, 354*pp*

Uematsu, H. and Yoshikawa, K. (2002). Seasonal changes in copulation and oviposition time of the diamondback moth, *Plutella xylostella* (Lepidoptera:Plutellidae). *Jap. J. Appl. Entomol., Zool.*, 46(2):81-87.

Ulmer, B., Gillott, C., Woods, D. and Erlandson, M. (2002). Diamondback moth, *Plutella xylostella* (L.) feeding and oviposition preferences on glossy and waxy *Brassica rapa* (L.) lines. *Crop Protec.*, 21(4):327-331.

Uma-Shankar., Bar, U.K. and Raju, S.V.S. (2005). Impact of intercropping in cauliflower on diamondback moth, *Plutella xylostella* (L.). *Ind. J. Pt. Protec.*, 33(1):43-47.

Umeya, K. and Yamada, H. (1973). Threshold temperature and thermal constants for development of the diamondback moth, *Plutella xylostella* (L.) with reference to their local differences. *Jap. J. Appl. Entomol. Zool.*, 17 (1):19-24.

Vastrad, A.S., Lingappa, S. and Bavanagoud, G.K. (2003). Management of insecticide resistant population of diamondback moth, *Plutella xylostella* (L) (Yponomeutidae:Lepidopteara). *Pest Managt. Hort. Ecosy.*, 9(1):33-40.

Verkerk, R.H.J. and Wright, D.J. (1996). Multitrophic interactions and management of the diamondback moth: a review. *Bull. Entomol. Res.*, 86:205-216.

Verma, A.N. and Sandhu, G.S. (1968). Chemical control of diamondback moth, *Plutella xylostella* (Curtis). *J. Res. Punjab. Agric. Univ.*, 5:420-423.

Vet, L.E.M. and Dicke, M. (1992). Ecology of infochemicals use by natural enemies in tritrophic context. *Ann. Rev. Enotomol.* 37:141-172

Wakisaka, C.M., Tsukuda, S.R. and Nakasuji, F. (1992). Effects of natural enemies, rainfall, temperature and host plants on survival and reproduction of the diamondback moth and other crucifer pests. In: Management Diamondback Moth and other Crucifer Pests. *Proc. II Interntl. Workshop.* A.V.R.D.C. Taiwan, 15-36*pp*

Wakisaka, S., Tsukuda, R. and Nakasuji, F. (1991). Life tables of the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera:Yponomeutidae) and effects of rainfall, temperature and host plants on survival and reproduction. *Jap. J. Appl. Entomol. Zool.*, 35(2):115-122.

Walunj, A.R., and Pawar, S.A. (2004). Evaluation of spinosad against diamondback moth, (*Plutella xylostella* L.) on cabbage. *Tests Agrochem. Cult.*. 25:4-5.

Wan, M.T.K. (1970). Bionomics and control of the diamondback moth, *Plutella xylostella* L. (*P. maculipennis* Curt.) (Lepidotera:Plutellidae) in Sarawak (Malaysian Borneo). *Sarawak-Museum J.*, 18:36-37.

Wang, K., Tsai, J.H. and Harrison, N.A. (1997). Influence of temperature on development, survivorship and reproduction of buckthorn aphid (Homoptera: Aphididae). *Ann. Entomol. Soc. Am.*, 90:62-68.

Wang, W. and Chen, W. (1992). Life tables of diamondback moth, *Plutella xylostella* (L.) and evaluation of insecticides. *J. South China Agric. Univ.*, 13(4):77-80.

Ware, G. W. and Whitacre, D. M., (2004). An Introduction to Insecticides. In: The Pesticide Book. (Ed. 6), Meister Pro Information Resources, Willoughby, Ohio.

Warthen, J.D. (1979). *Azadirachta indica.* A source of use feeding inhibitors and growth regulators. U. S. Dep. Agric., A.R.R.N.E., 4.

Western Committee on Crop Pests (1995). Min. 34th Ann. Meeting, October 19-21, *Victoria, British Columbia,* 44 *pp*

Western Committee on Crop Pests (2001). Min. 41st Ann. Meeting, October 15-16, *Banff, Alberta*. 71 *pp*

Wu, G., You, M.S., Zhao, S.X., Wu, G., You, M.S. and Zhao, S.X. (1999). Studies on the insensitivity of acetylcholinesterase to organophosphates and carbamates in *Plutella xylostella* (L.). *Wuyi Sci., J.,* 15:100-103.

Xu, Y., Liu, T., Leibee, G.L. and Jones, W.A. (2004). Effects of selected insecticides on *Diadegma insulare* (Hymenoptera:Ichneumonidae), a parasitoid of *Plutella xylostella* (Lepidoptera:Plutellidae). *Biocont. Sci. Tech.,* 14:713–723.

Yadav, D.N., Patel, R.C. and Manjunath, T.M. (1975). Seasonal activity of *Apanteles plutellae* (Kurdj). A larval parasite of *Plutella xylostella* (L.) at Anand (Gujarat, India). *Ind. J. Pt. Protec.,* 3:111-115.

Yadava, P.R., Sachan, J.N. and Yadav, C.P.S. (1974). Bionomics of the diamondback moth, *Plutella xylostella* Linn, on cauliflower. *Bull. Entomol.*, 15:87-91

Yamada, H., and Kawasaki, K. (1983). The effect of temperature and humidity on the development, fecundity and multiplication of the diamondback moth, *Plutella xylostella* (L.). *Jap. J. Appl. Entomol. Zool.*, 27:17-21.

Yamada, K., Tanaka, T., Fahmy, A.R. and Miyata, T. (1993). Laboratory evaluation of the biological fitness of chlorfluazuron resistant and susceptible strains from the same origin of the diamondback moth, *Plutella xylostella. Appl. Entomol. Zool.,* 28(3):396-399.

Yang, P.J., Carey, J.R. and Dowell, R.V. (1994). Temperature influences on the development and demography of *Bacterocera dorsalis* in China. *Environ. Entomol.,* 23:971-974.

Yu-Rong, H. LiHua, Lu., XiongFei, Pang., Y.R, He., L.H, L.u. and Pang, X.F. (2000). Simulation of control effectiveness of several parasitoids against population of the diamondback moth (*Plutella xylostella* L.). *J. South China Agric. Univ.,* 21(2): 18-20.

Zhao, J.Z., Wu, S., Gu, Y. and Ju, Z. (1996). Strategy of insecticide resistance management in the diamondback moth. *Sci. Agric. Sincia,* 94:541–546.

Zhou, A.N., Chen, J.M., Ma, X.L. and Ma, C.Z. (1992). Development and feeding dynamics of the diamondback moth (Lepidoptera:Plutellidae) at different temperatures. *Acta Agric.,* 8(4):96-98.